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„The Effects of Complex Training Interventions on Measures of Performance and Body Composition: An in-depth Analysis“

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Abstract:

Sports performance in various disciplines is highly dependent on variables, such as strength or power (Greenwood, 2014). While traditional resistance training is believed to be most efficient for developing maximal strength, plyometric training is said to most efficiently enhance power (Cormie, McGuigan, & Newton, 2011b). In order to provide athletes and trainers with an efficient training method tackling both of these variables, a combination form called "complex training" was proposed and found to be effective (Ebben & Watts, 1998; Fleck & Kontor, 1986). By combining higher-load resistance exercises with lower-load plyometric exercises this method shall evoke a neuromuscular phenomenon called "post-activation potentiation" (Sale, 2002). This is believed to improve two performance measures simultaneously. As research shows conflicting opinions on this matter, this systematic analysis was conducted to analyze and review the current scientific literature. After screening 12,421 studies gathered from the databases PubMed, Web of Science Core Collection, SPORTDiscus, CINAHL and SCOPUS, 41 studies, which met the defined inclusion criteria, were included in the analysis. The results show that complex training appears to be an effective and efficient training method to improve strength, jump and partly sprint performance. Concerning agility, body fat percentage and sport-specific performance varying results are reported. Overall, complex training is more effective than no training. A definite trend for its superiority over other training methods cannot be reported, however, it does not seem to be inferior either. More valid conclusions would require more extensive (meta-) analytic procedures.

Zusammenfassung:

In zahlreichen Sportarten ist die Leistungsfähigkeit stark abhängig von Variablen wie etwa Maximalkraft oder Power (Greenwood, 2014). Während traditionelles Kraft-/Widerstandstraining als am effektivsten zum Aufbau der Maximalkraft angesehen wird, erscheint plyometrisches Training die Schnellkraftfähigkeiten am effektivsten zu beeinflussen (Cormie, McGuigan, & Newton, 2011b). Um AthletInnen und TraininerInnen mit einer Trainingsmethode auszustatten, welche beide dieser Variablen trainiert, wurde eine Kombinationsform namens „Complex Training“ entwickelt und für effektiv empfunden (Ebben & Watts, 1998; Fleck & Kontor, 1986). Durch die Kombination hochintensiver Kraftübungen mit weniger intensiven plyometrischen Übungen soll diese Methode die sogenannte „Postaktivierungs-Potenzierung“ (Sale, 2002) evozieren, um folglich zwei Leistungsparameter positiv zu beeinflussen. Da die wissenschaftliche Landschaft geteilter Meinung zu dieser Thematik ist, wurde diese systematische Überblicksarbeit verfasst, um aktuelle Fachliteratur detailliert zu analysieren. Von 12.421 gesammelten Studien aus den Datenbanken PubMed, Web of Science Core Collection, SPORTDiscus, CINAHL und SCOPUS entsprachen 41 Studien den Einschlusskriterien und wurden zur weiteren Analyse herangezogen. Aus den Ergebnissen geht hervor, dass Complex Training eine effektive und effiziente Trainingsmethode zur Verbesserung der Kraft-, Sprung, und (teilweise) Sprintleistung darstellt. In Bezug auf die Variablen Agilität, Körperfettanteil und sportspezifische Leistungsfähigkeit wurden unterschiedliche Ergebnisse erzielt. Es hat sich erwiesen, dass Complex Training generell zu besseren Ergebnissen führt als kein Training. Obwohl ein klarer Trend hinsichtlich seiner Überlegenheit gegenüber anderen Trainingsmethoden nicht zu erkennen war, scheint auch keine Unterlegenheit vorzuliegen. Gesichertere Aussagen würden jedoch genauere (meta-analytische) Verfahren voraussetzen.

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1 Introduction

The importance of achieving optimal performance within the optimal amount of time invested in the actual training process is a very fundamental issue in resistance training and athletics in general. One major goal for athletes, coaches and professionals is to maximize the athletes'/clients' abilities in different areas of physical performance (Greenwood, 2014, p. 11). Therefore, different training methods are carried out to achieve a certain outcome. High load resistance training, for example, is said to be beneficial to primarily increase maximal strength development. Although, the power component is trained as well, it only increases significantly if the subject shows a generally lower training status (Cormie, McGuigan, & Newton, 2011b, p. 135). On the contrary, research suggests that training protocols including lighter loads and ballistic or plyometric exercises tackle primarily the power output; but especially, that they are "very effective at improving maximal power output in sports-specific movements" (Cormie et al., 2011b, p. 136). Particularly plyometric training has been intensively investigated and described in recent years to increase power (Chu, 1983, 1998; G. Davies, Riemann, & Manske, 2015; Lundin, 1991; Markovic, 2007). Considering that maximal muscular power is highly "influenced by a wide variety of neuromuscular factors" it is important to recognize power here as "neuromuscular power". These influential factors are, among others, "[…] motor unit recruitment, firing frequency, synchronization and inter-muscular coordination, […] the time available to develop force, storage and utilization of elastic energy, interactions of contractile and elastic elements, potentiation of contractile and elastic filaments as well as stretch reflexes" (Cormie, McGuigan, & Newton, 2011a, p. 30f.).

In the strive towards achieving a (time) efficient training method which tackles both neuromuscular power and strength, a new method has been investigated and first described by Fleck and Kontor (1986). This method called "complex training" is believed to enhance both of the mentioned parameters in the same conditioning session (Greenwood, 2014). Ebben and Watts (1998, p. 18) describe complex training as a method which "[…] alternates biomechanically comparable high-load weight training and plyometric exercises in the same workout". This concept has been repeatedly investigated on both its acute (Baker, 2003; Bevan, Owen, Cunningham, Kingsley, & Kilduff, 2009; Ebben, Jensen, & Blackard, 2000; Jones & Lees, 2003) and non-acute or long-term effects (MacDonald, Lamont, & Garner, 2012; Mihalik, Libby, Battaglini, & McMurray, 2008). However, the outcomes are very diverse, and the study designs differ significantly in multiple areas.

To begin with, the first discrepancies already appear when it comes to a consistent definition of the training method itself. While Fleck and Kontor (1986) define complex training as executing several sets of a heavy load exercise followed by several sets of a low load explosive exercise, Chu (1983, p. 65f.) states that the sets of the different exercises should be executed in an alternating fashion. Further sources (Ebben, 2002, p. 42; Ebben & Watts, 1998, p. 18) refer to complex training in a similar fashion, but others use both the terms *complex* and *contrast training* and the alternating and block design interchangeably, and thus confusing the terms even more (Duthie, Young, & Aitken, 2002; Young, Jenner, & Griffiths, 1998).

Aside from the conflicting and inconsistent concepts of what complex training actually looks like, its underlying mechanisms and effects are constantly investigated. The acute effects of complex training are often put into relation with the concept known as "post activation potentiation" (PAP) (Kilduff et al., 2007, p. 1134). This term is described by Sale (2004, p. 386) as "[…] an increase in muscle isometric twitch and low frequency tetanic force following a 'conditioning' activity". To explain PAP, several mechanism are proposed, among which Aagaard, Simonsen, Andersen, Magnusson, and Dyhre-Poulsen (2002, p. 2313) deliver a suitable one by stating that PAP results out of increased "motoneuron potentials" after a heavy-load stimulus. With reference to Baker (2003) and Brandenburg (2005) such an increase in muscle isometric twitch and higher power output may be triggered through complex training. Although this phenomenon has been investigated repeatedly, according to Seitz and Haff (2016, p. 232) "[…] conflicting results have been reported regarding the extent of improvement: overall, increases, no changes, and decreases have been observed".

Ebben et al. (2000), for example, tried to investigate the effects of certain complex pairs on different force and power parameters by testing ten male NCAA basketball players according to those variables. Their "[…] results indicate that there is no heightened excitability of the nervous system", but also no significant disadvantage in this training method. "Therefore, complex training may be a useful training strategy because of the organizational advantages of performing weight and plyometric exercises in the same training session" (Ebben et al., 2000, p. 451).

Concerning the overall effectiveness of complex training, the current research environment is rather inconsistent as well. Varying results can be found in different studies and many among these results are not entirely comparable as their study designs vary considerably, or are in certain respects insufficient. Aside from the general conceptualization of the method itself, crucial variables for the assessment are among others: the duration of the intervention, the subjects' training statuses, the exercise selection and number of exercises, and the indicated rest period (if indicated at all).

Concerning the duration, selected recent studies on CT range between 4 weeks (Dodd & Alvar, 2007; Mihalik et al., 2008) over 6 weeks (MacDonald et al., 2012; Stasinaki et al., 2015) up to 8 weeks (Lyttle, Wilson, & Ostrowski, 1996) or even 18 weeks (Veliz, Requena, Suarez-Arrones, Newton, & de Villarreal, 2014) of duration, with 2 to 3 (Stasinaki et al., 2015) sessions per week. These numbers, with a minor exception of the 4 weeks, seem to be reasonable as after this amount of time a certain effect may be expected. The 6 weeks (MacDonald et al., 2012, p. 424) were considered by the authors as "[…] relatively short, with respect to inducing muscle-to-muscle architecture; however [it is] the duration in which there was uninterrupted access to the subjects". Nevertheless, for validity reasons, longer interventions should be preferred.

The number of participants is occasionally very small which may result in relatively small groups and a decrease in validity; especially, if there is a high drop-out rate. Furthermore, the subjects often show very different training statuses and are rather vaguely described, ranging from "not been involved in any specific strength or plyometric training" (Lyttle et al., 1996, p. 173), or "moderately trained" (Stasinaki et al., 2015, p. 2560), to "recreationally trained" (MacDonald et al., 2012, p. 424). However, more precise descriptions, such as "[a]ll subjects were division II junior college baseball players […] and had at least 1 year of previous resistance training experience" (Dodd & Alvar, 2007, p. 1178) are given in other studies.

Furthermore, in some studies the resting periods between the sets are not always indicated for the different groups (Dodd & Alvar, 2007) or not indicated at all (Lyttle et al., 1996), which is one of the most inconsistent factors in current research on complex training.

Although the studies on acute effects of complex training, also in connection with PAP, are numerous and build a broad field of reference, studies on long-term effects of this training method are comparatively rare (MacDonald et al., 2012; Stasinaki et al., 2015). Additionally, a special factor in this matter has been almost uninvestigated so far: the question if the mentioned PAP effect itself can be trained or elevated over time. Previous research by Mitchell and Sale (2011) and McBride, Nimphius, and Erickson (2005) has shown, that the PAP-effect after a heavy-load stimulus results in higher performance in an explosive movement and sprints, but very few studies have analyzed whether the potentiation effect itself increases over time, when it is induced in a complex training setting (Tsimachidis, Patikas, Galazoulas, Bassa, & Kotzamanidis, 2013; Tsimahidis et al., 2010). In this context, Lesinski, Muehlbauer, Büsch, and Granacher (2014, p. 104) pointed out that definite conclusions on whether the increased performance in those studies was due to a PAP-effect or not could not be drawn, as the authors only compared two test results. Therefore, they argue, it is not clear whether the higher performance in the second test was due to an increased PAP, or due to fatigue in the first test or an adaptation process during the intervention. Consequently, clear conclusions about a possible long-term adaptation of the post-activation potentiation following a complex training intervention cannot be drawn so far.

Generally, current research on complex training partly lacks systematically well-designed long-term studies, which would support the efficiency and superiority of this method (Docherty, Robbins, & Hodgson, 2004, p. 55; Seitz & Haff, 2016, p. 239). Therefore, this thesis aims at carrying out an in-depth systematic analysis of the current research environment of long-term studies on complex training. Furthermore, it should provide a specific model study design for further research in this field. This model is set to consider all the previously described crucial factors and investigate if the potentiation effect triggered in a complex training setting is subject to change after certain training period.

1.1 Research Questions and Aims

- Which long-term effects does complex training have on various measurements of power, strength and body composition?
- How might different study designs influence these outcomes?
- What does the current scientific literature say about the efficiency of complex training methods?
- How should a high-quality intervention study on complex training look like, considering the occasional inconsistencies in recent research on this matter?

This thesis is a continuation of a previous investigation analyzing complex training studies by Übellacker and Bauer (2017). The authors collected over 8,000 studies and systematically screened the scientific literature. Respecting specific in- and exclusion criteria, they narrowed this accumulation down to 29 studies for further systematic analysis. To the best of the authors knowledge, the data is currently prepared for meta-analysis. However, as the authors had to use strict in- and exclusion criteria to suit their analysis, they possibly had to neglect certain important studies because of a lack of indicated data or too loosely knit study designs, even if they could have been labeled of good quality and relevance in the field. For example, the study by Tsimachidis et al. (2013) was not included; presumably, because the authors assessed sprint speed and not times. Further, other studies, such as Fletcher and Hartwell (2004), Lee, Lee, and

Yoo (2014), Labib (2013), or Kramer, Morrow, and Leger (1993) were excluded as they are investigating sport-specific measures. Additionally, the authors carried out a search process, which ended in April 2017. However, in the meantime new studies were published (Almoslim, 2016; Fathi et al., 2018; Hammami, Gaamouri, Shephard, & Chelly, 2018; Hammami, Negra, Shephard, & Chelly, 2017a; Rodríguez-Rosell, Torres-Torrelo, Franco-Márquez, González-Suárez, & González-Badillo, 2017) which could be of interest for these research questions.

Studies, such as the mentioned ones, shall be considered in this analysis in the attempt to draw a more differentiated picture of the current state of knowledge on this topic. Based on this in-depth analysis of all the eligible studies, this thesis is additionally, aiming at providing a 'high-quality' model intervention as a suggestion for further research.

2 Theoretical Contextualization

The following chapter treats the mechanisms crucial to the training method(s) under review. Factors, such as, the importance of strength and power for the force-velocity-curve, the interaction between load and velocity, or the phenomenon known as "post-activation-potentiation" (PAP) (Sale, 2004) will be discussed in the following section.

2.1 The Force-Velocity-Relationship

To address the specific underlying principles of the training method under review, it is important to first discuss the general concepts of strength and power and their interrelation. According to Stone, Moir, Glaister, and Sanders (2002) strength can be described as "the ability to produce force". The authors, further, mention Newton's second law "F = m·a" as the core of force production and link this concept biomechanically to certain muscular phenomena, such as "the type of contraction, the rate of muscle activation and the degree of muscle activation". Power is then, defined as the following (Figure 1):

$$\begin{aligned}\text{Power} &= \frac{\text{Work}}{\text{Time}}\\ &= \frac{\text{Force} \times \text{Distance}}{\text{Time}}\\ &= \text{Force} \times \text{Velocity}.\end{aligned}$$

Figure 1: Power (Haff & Nimphius, 2012, p. 3)

According to Stone et al. (2002, p. 88) power can either be expressed as “[…] an average over a range of motion or as an instantaneous value occurring at a particular instant during the displacement of an object”. Peak power, then, means the highest value during such a displacement process; whereas maximum power is “[…] the highest peak power output one is capable of generating under a given set of conditions” (Stone et al., 2002, p. 88f.). Many state that maximizing the maximum power output is one of the main factors for success in sports across a majority of disciplines (Haff & Nimphius, 2012, p. 2; Stone et al., 2002, p. 89). Even though Knudson (2009, p. 1905), argues that this statement should be encountered with caution, as most sport-specific skills are highly dependent on other performance variables such as “[…] speed, force, technique, or some combination of these variables.”, power still constitutes, among others, a very important performance variable.

In general, a close “inverse” relationship between force (or strength) and velocity can be seen in the traditional force-velocity curve (figure 2). Accordingly, the level of force decreases as the velocity increases and vice-versa. This circumstance stands in close relation to the muscles’ general ability of building actin-myosin cross-bridges. Cormie et al. (2011a, p. 19) explain here, that “[…] because it takes a fixed amount of time for cross-bridges to attach and detach, the total number of cross-bridges attached decreases with increasing velocity of muscle shortening. Due to the fact that the amount of force generated by a muscle depends on the number of attached cross-bridges, force production decreases as the velocity of the contraction increases […]”. As a result, the peak power level can neither be at the point of highest force nor velocity. Peak power, therefore, occurs at the shift between optimal velocity and force (Figure 2)

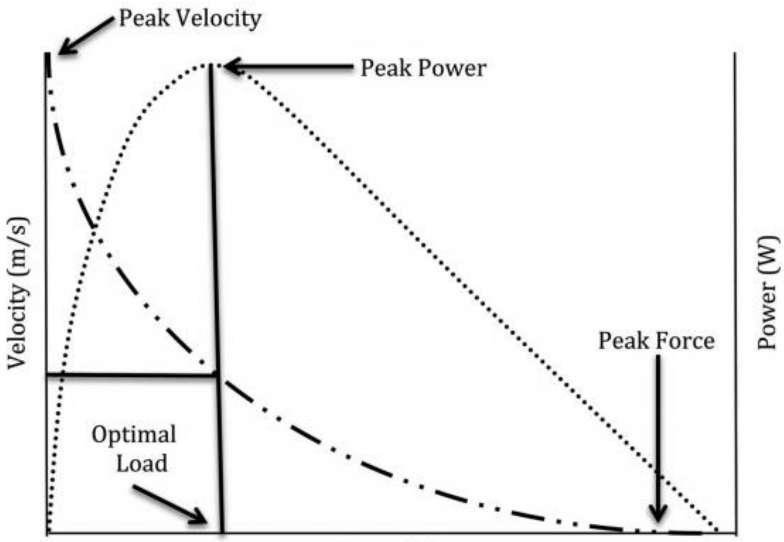

Figure 2: Force-Velocity-Curve (Haff & Nimphius, 2012, p. 4)

In order to tackle power output in training, Haff and Nimphius (2012, p. 3) conclude that three main factors have to be considered. First, the maximum muscular strength should be on a high level, due to its direct influence on the force variable of the equation. Second, it is crucial to acquire a high "rate of force development" to be able to rapidly produce high forces; and third, "[…] it is important to develop an ability to express high forces as the velocity of shortening increases".

A reoccurring influential variable in this above-mentioned list is strength. In line with the requirements stated by Haff and Nimphius (2012), Cormie et al. (2011b, p. 127f.) support the argument of the importance of strength. Interestingly, however, they highlight that the degree of increase in maximum power is dependent on the strength level of the subjects tested. Accordingly, athletes displaying a greater level of maximal strength have a lower potential to further increase both their strength and power when targeting only their maximal strength, whereas weaker subjects show a higher potential in this respect. Consequently, in early training stages special emphasis may be put on maximal strength development to simultaneously increase power. For more advanced athletes, more specialized training methods seem to be more efficient as the basic muscular and neuronal qualities are already apparent. Through this kind of more targeted training more specific areas of the force-velocity curve may be trained (Cormie et al., 2011b, p. 129; Haff & Nimphius, 2012, p. 4).

The second important variable is the "rate of force development". According to Haff and Nimphius (2012, p. 5) this variable stands for the "[…] rate at which force is expressed during a sporting movement". The rate, therefore, influences rather the force-time- than the force-velocity-components of a movement. This rate is measured at specific time points (e.g. 200ms) and gives information on the speed and forcefulness of a contraction (Figure 3). Specific forms of training therefore affect this rate differently.

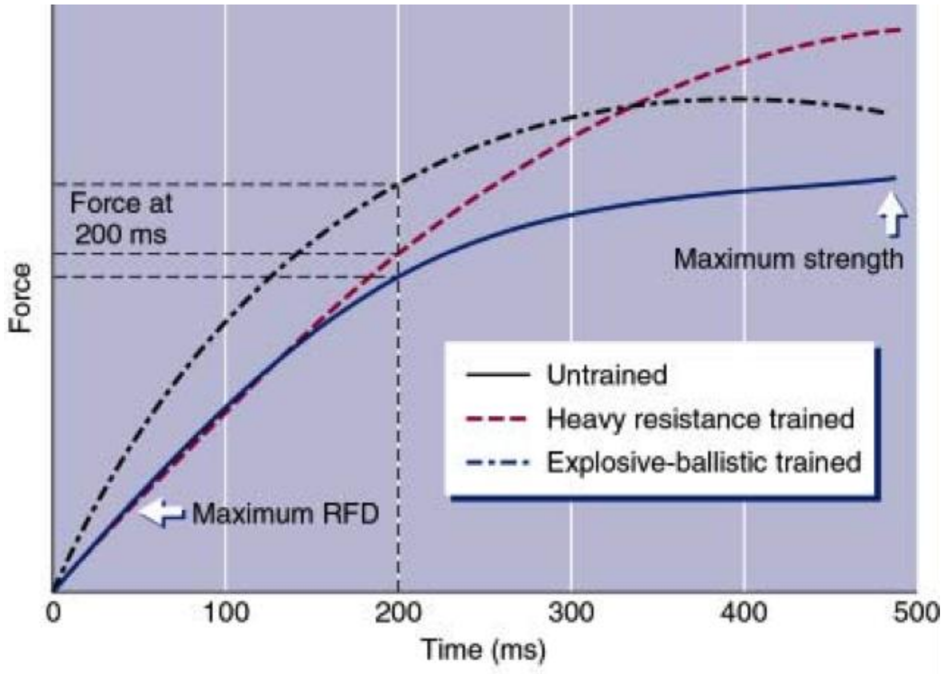

Figure 3: Rate of Force Development (Baechle & Earle, 2008)

As this variable is more about the time and velocity of the actual muscular potential, Knudson (2009, p. 1905) even argues that this factor may be more reliable and influential than the mechanical peak power alone.

2.2 Load and Velocity Interactions

The above-mentioned principles build a good theoretical basis, but for actual training practice actual quantified values serve as guidelines for proper workout design. A crucial factor here is how the muscular and neuronal circumstances may be targeted and altered through training. In this respect, assignments of load, repetitions, and velocity of exercise execution represent vital determinants of training design. Various sources give different load and repetition prescriptions to achieve specific training outcomes. In practice certain simplified load prescriptions and tables may serve as good orientation guidelines for specific training goals (Table 1).

Table 1: Load and Repetition Assignments Based on Training Goal (Baechle & Earle, 2008)

Training goal	Load (%1RM)	Goal repetitions
Strength	85 or higher	Up to 6
Power:		
Single-effort event	80-90	1-2
Multiple-effort event	75-85	3-5
Hypertrophy	67-85	6-12
Muscular endurance	Up to 67	12 or more

More in-depth prescriptions, however, may help to further increase training efficiency. According to Hohmann, Lames, and Letzelter (2010, p. 72ff.) the major influential factors for high strength development are “muscle cross-section” and “the amount of fast-twitch fibers”. However, neuronal factors, such as activation potentials of the muscle or inter- and intramuscular coordination, play at least a similarly significant role in muscle strength. Within this domain, three factors are important for a maximum contraction of a muscle: maximum recruiting of motor units; maximum firing of motor units at an early stage of the contraction; and maximum synchronization of the recruited motor units. If these qualities are satisfied, higher force can be generated in a shorter period of time. Due to these influential factors of muscle cross-section, fiber types and neuronal firing, Tidow (1994) defines two different methodological categories for strength training: “muscle cross-section methods” (MCM) and “neuronal activation methods” *(NAM).* These categories, in addition to load and repetition prescriptions, take the velocity or the intended velocity into consideration. Accordingly, Hohmann et al. (2010, p. 77), design training prescriptions as follows (Table 2):

Table 2: Training prescriptions for strength (adapted from Hohmann et al. (2010)

Method	Contraction and load	Intensity	Velocity	Repetitions	Sets	**Rest**
MCM: intensive bodybuilding method	Concentric submaximal strength until failure	80-95%	Slow	5-8	3-5	>2 mins
NAM: Explosive-strength method	Concentric submaximal strength	50-95%	Maximal	2-5	2-5	>3 mins

The combination of load and the (intended) velocity prescription, then, gives advice about the main area of strength production (neuronal capacity or muscle cross-section) which is primarily targeted in the respective method.

In this respect it is important to address a controversy concerning the movement velocity. Many scholars have found that movement velocities have high impact on training outcomes for strength and power training alike (Cormie et al., 2011b; T. Davies, Kuang, Orr, Halaki, & Hackett, 2017; González-Badillo, Marques, & Sánchez-Medina, 2011). In general, it is reported that exercises with lower loads executed at high velocities result in higher power output in fast movements, whereas lower velocities combined with higher loads result in lower outcomes (Cormie et al., 2011b, p. 138f.). Contrarily, Behm and Sale (1993) conducted a study in which the outcome suggested that the neuronal predisposition of moving heavy loads very rapidly has a positive influence on the actual training outcome. This hypothesis is, however, neither fully supported nor contradicted. Nevertheless, it can be concluded that current research supports the importance of both intended and actual velocity, and its effects on the neuronal capacity and power/strength production. In combination with specific load prescriptions these factors are crucial determinants for designing training programs.

2.3 Specific Training Methods

As elaborated above, the force-velocity relationship is vital for the performance of movement, as it represents the muscles' physiological and neurological ability to function under the influence of differing loads (Cronin, McNair, & Marshall, 2003, p. 148). The ability to use certain training parameters (load, intensity, velocity) in a way that they influence the muscle towards an intended purpose is, therefore, crucial for training practice. Using this knowledge, research has found certain movement techniques, which target specific areas of the force velocity curve.

Traditional strength training, for example, aims at a general increase in strength and muscle cross-section. These methods typically work with concentric submaximal contractions until failure. The loads are usually set at 70-80% of the one-repetition-maximum, and comparably slower execution velocities are used (Hohmann et al., 2010, p. 77; Zatsiorsky & Kraemer, 2016, p. 139f.). Aside from strength and cross-section increases, also elevated power has been recorded using traditional strength training. However, these increases have predominantly occurred in subjects with generally lower training statuses (Cormie et al., 2011b; Newton & Kraemer, 1994).

A major ‘issue’ when working with traditional strength training for power elevation is the so-called “deceleration phase” (Newton & Kraemer, 1994, p. 25). This phase occurs towards the moment when submaximal loads are moved in a concentric or eccentric fashion and have to be stopped at a certain point. According to Newton and Kraemer (1994, p. 25) this phase makes up almost a quarter of a movement when using the 1RM and may rise up to over 50% when moving 81% of the 1RM. To avoid this phase, *ballistic movements* are used to allow the athlete to accelerate over the entire time of the contraction. This results in higher concentric velocities, power, force and muscle activity during the entire range of motion (ROM), and consequently in higher training outcomes for both experienced and less experienced athletes (Cormie et al., 2011b; Kyröläinen et al., 2005; McBride, Triplett-McBride, Davie, & Newton, 2002).

Most explosive / ballistic movements initially include a movement in the direction other than the intended one (countermovement). This results in a number of neural and mechanical processes which are channeled in the term “stretch shortening cycle” (SSC) (Newton & Kraemer, 1994, p. 26). In this cycle the respective muscle is first stretched in an eccentric movement and then rapidly contracts concentrically, resulting in higher performance. According to Komi & Häkkinen (1989; in: Hohmann et al., 2010, p. 81) this increase in performance roots in the storage of elastic energy in the muscles, tendons and ligaments which is released in the following concentric contraction. This kind of movement is also known as *plyometric movement* and has been proven to be beneficent for jumping ability (Lyttle et al., 1996; MacDonald et al., 2012). According to Newton and Kraemer (1994, p. 26) “[…] plyometric training increases the overall neural stimulation of the muscle, and thus force output, but qualitative changes are also apparent”.

2.4 Complex Training

Considering the different underlying principles of strength and power training, research has made an attempt to find a training method which is efficiently tackling both the strength and power component of athletic performance. Consequently, a combination of strength and power training was implemented by combining high load resistance training exercises with low load plyometric exercises. The history of this training method and its physiological core-mechanism – the post-activation potentiation – will be covered in the following section.

2.4.1 Conflicting Definitions

Fleck and Kontor (1986), with reference to a lecture by Verhoshansky, were the first to mention “complex training” as executing a block of several sets of a low load explosive exercise after a block of sets of a heavy load exercise and declare this as one “complex” in a complex training protocol. Chu (1983, p. 65f.) however, stated that in complex training the plyometric exercises should be placed “between the sets of the particular lift” as the “[…] body remains in the arousal or heightened state of excitement at the conclusion of a heavy set [and] the athlete can take advantage of this physiological state”. Young et al. (1998), then, used both “contrast” and “complex” training reciprocally for a training protocol with an alternating set-by-set design. Ebben and Watts (1998, p. 18) tried to clarify the term in their review by defining it as “[…] training [which] alternates biomechanically comparable high-load weight training and plyometric exercises in the same workout”. However, this definition still did not exactly state whether every single heavy load set was followed by a plyometric exercise or only every block. Therefore, in a later definition by Ebben (2002, p. 42) the wording “set for set” was included. Adding further ambiguity to these terms, Duthie et al. (2002, p. 530) referred to “complex training”, again, as being “[…] various sets of groups/complexes of exercises performed in a manner in which several sets of a heavy resistance exercise are followed by sets of a lighter resistance exercise” – meaning a block design – and “contrast training” as “ […] a workout that involves the use of exercises of contrasting loads, that is, alternating heavy and light exercises set for set.”

In order to follow a clear structure when referring to the different complex training forms in this thesis, the following table (Table 3) shall work as an overview of the used terminology. Further regimes which do not show any complex training fashion are referred to as *alternative training methods* (e.g. resistance training, plyometric training, or Olympic style weight lifting). Protocols, which combine two training methods but are not complex training in the narrow sense are referred to as *alternative periodization methods.* These include block-wise periodization (e.g.: two weeks of strength training followed by two weeks of plyometric training) or compound training (e.g.: plyometric and strength training in the same session but with more than 15 minutes rest in between). Additionally, this category applies if a certain training method uses a certain sequence of exercises of a complex training method in a reverse order (e.g. reverse complex training, reverse block set complex training, reverse block complex training).

Table 3: Complex Training Models (adapted from Übellacker and Bauer (2017, p. 11)

Complex Training

Complex Pair 1	High-Load Exercise
	Plyometric Exercise
	High-Load Exercise
	Plyometric Exercise
	High-Load Exercise
	Plyometric Exercise
Complex Pair 2	High-Load Exercise
	Plyometric Exercise
	High-Load Exercise
	Plyometric Exercise
	High-Load Exercise
	Plyometric Exercise

Block Set Complex Training

Complex Pair 1	High-Load Exercise
	High-Load Exercise
	High-Load Exercise
	Plyometric Exercise
	Plyometric Exercise
	Plyometric Exercise
Complex Pair 2	High-Load Exercise
	High-Load Exercise
	High-Load Exercise
	Plyometric Exercise
	Plyometric Exercise
	Plyometric Exercise

Block Complex Training

Strength Block	High-Load Exercise
	High-Load Exercise
	High-Load Exercise
	High-Load Exercise
	High-Load Exercise
	High-Load Exercise
Plyometrics Block	Plyometric Exercise
	Plyometric Exercise
	Plyometric Exercise
	Plyometric Exercise
	Plyometric Exercise
	Plyometric Exercise

2.4.2 Post-Activation Potentiation

As mentioned before, the combination of certain training methods aims at affecting multiple performance measures in one training session. The alleged benefit of complex training is very often mentioned in connection with a physiological phenomenon known as *post-activation potentiation* (Aagaard et al., 2002; Baker, 2003; Brandenburg, 2005; Chen, Lo, Wang, Yu, & Peng, 2017). According to (Sale, 2002, p. 138) “PAP is an increase in muscle twitch and low-frequency tetanic force after a ‘conditioning’ contractile activity”. This effect roots in an elevated “phosphorylation of myosin regulatory light chains” which leads to a higher “actin-myosin interaction”. As seen in 2.1. this actin-myosin interaction is vital for building cross-bridges (Cormie et al., 2011b). Accordingly, if PAP causes a higher actin-myosin interaction, more cross-bridges can be built faster which results in higher and faster power generation. In general, it is said that PAP is induced after a series of twitches or isometric contractions (sustained maximal voluntary contraction MVC) (Sale, 2002) (Figure 4). The preceding conditioning contraction results in a faster twitch and an increase in force.

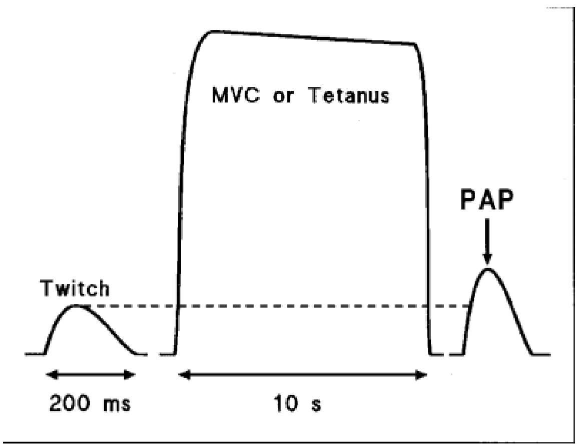

Figure 4: Post-Activation Potentiation after an induced twitch, an MVC or tetanus resulting in higher force and shorter twitch time. (Sale, 2002, p. 139)

However, analyzed under the light of the force frequency-relationship, it is crucial to note that the force is only elevated in the low frequency phase of the contraction. Figure 5 illustrates that PAP is capable of inducing a higher force both after isometric and concentric contractions and causing an elevated rate of force development (Haff & Nimphius, 2012; Sale, 2002) (see 2.1).

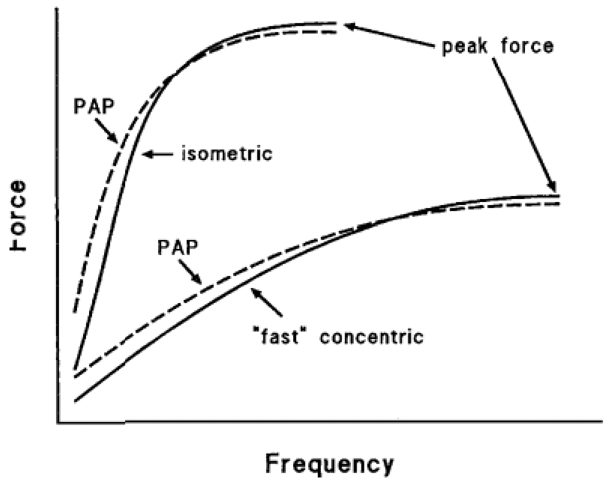

Figure 5: Interaction between PAP and contraction type (Sale, 2002, p. 140)

Due to this elevated rate, PAP is able to shift the curve of the load(force)-velocity-relation to the right and upwards (compare Figure 2) (Sale, 2002).

2.4.3 Impact on Training Design

Complex training protocols benefit from the mentioned PAP-effect to induce higher power after a conditioning exercise and use this potentiated state in the muscles for better training outcomes (Chu, 1983, p. 65f.). However, several parameters, such as the subjects' training status, the selection of conditioning activities, the rest periods or the load prescriptions have to be considered for efficient training design (Seitz & Haff, 2016).

Concerning the subjects' training status Seitz and Haff (2016) draw similar conclusions as Haff and Nimphius (2012) or Cormie et al. (2011b) stating that individuals with a higher baseline strength level and more experience in strength training profit more from such a specialized training method than do weaker individuals. This could root in a heightened "fatigue resistance" after heavy load stimuli in better trained athletes (Chiu & Barnes, 2003; Hamada, Sale, & Macdougall, 2000). Additionally, the greater amount of type II muscle fibers and the resulting higher phosphorylation of myosin light chains may result in higher outcomes for more experienced athletes (Aagaard & Andersen, 1998; Seitz & Haff, 2016).

The type of conditioning activity is also mentioned as a core determinant in complex training. According to Seitz and Haff (2016) "plyometric and traditional high-intensity" conditioning activities result in higher PAP than do exercises with lower intensity or isometric contractions. The superiority of plyometric exercises to induce PAP may be explained by the lower amount of fatigue produced by such activities, or the higher rate of recruiting type II fibers already in the CA, which are crucial for fast power production (Desmedt & Godaux, 1977; Seitz & Haff, 2016).

Furthermore, rest periods after the conditioning activity are a crucial factor for the amount of PAP and the performance in a subsequent exercise (Seitz & Haff, 2016). Current research indicates that rest intervals between five and seven minutes after the CA result in greater PAP than intervals shorter than four minutes (Seitz & Haff, 2016; Wilson et al., 2013, p. 857f.). However, this, again, depends both on the type of the CA and the overall training level of the subjects. Accordingly, after high-intensity CAs more rest is needed than after plyometric CAs; and stronger athletes may need less rest than weaker ones (Seitz, de Villarreal, & Haff, 2014, p. 712; Seitz & Haff, 2016).

Similar conclusions are mentioned, when it comes to the load prescriptions of the conditioning exercises. While stronger individuals show greater PAP after 1RM CAs, weaker subjects show higher rates after slightly sub-maximal loads. Nevertheless, in general, higher loads are said to induce a higher potentiation effect than lower loads (Seitz & Haff, 2016). However, other sources report conflicting results. Freitas, Martinez-Rodriguez, Calleja-González, and Alcaraz (2017) state that larger effect sizes were observed for intensities below 85% of the one repetition maximum for jump and sprint performance. Similarly, Wilson et al. (2013, p. 857) concluded that "optimal potentiation" was achieved after CAs with intensity of 60% to 84% of the 1RM. Nonetheless, these studies did not or only partly consider the subjects training status, therefore, it can be concluded that, in general, high intensities should be used for evoking PAP (Ebben & Watts, 1998, p. 23).

3 Methodology

The methodological procedures were in close relation to the previous study by Übellacker and Bauer (2017). The main focus is set on a narrative and qualitative assessment of the included studies. A broader catalog of in- and exclusion criteria allows examination of a broader spectrum of studies and aims at identifying both the practical relevance of the training method and the scientific relevance of recent research in the field. All data are presented as mean and standard deviation (SD) values if not otherwise reported.

3.1 Search Process

Respecting a new set of criteria, the search procedure (see below) used by Übellacker and Bauer (2017) was repeated both for the initial time span and the time span from April 2017 up to now in order to update the list of possibly eligible studies and include the most recent findings. The search string was applied in the following electronic databases: PubMed, Web of Science Core Collection, SPORTDiscus, CINAHL and SCOPUS.

“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"))

3.2 In- and Exclusion Criteria

In order to consider a wider variety of studies in this analysis, the criteria are defined more openly than in the referenced thesis. Especially, when it comes to the outcome variables the inclusion criteria will allow a greater variety, as the possible effects of complex training should not be restricted. Similar to the work by Übellacker and Bauer (2017), in order to be eligible, the studies have to:

1) include healthy participants who are older than 14 and younger than 50;
2) be original investigations published in peer-reviewed journals;
3) show a ‘long term’ study design lasting longer than 4 weeks with at least 8 training sessions;
4) feature a training protocol in which a combination of resistance and power exercises is done in one and the same training sessions. The break between the exercises has to be shorter than 15 minutes and should be carried without any kind of exhausting physical activity; AND lighter, power related exercises are carried out after heavy strength exercises in at least one group;
5) be controlled trials (no simple pre-post design; other training regimes can also be defined as control group);
6) investigate the outcome measures jump (height or peak power), sprint (different distances), 1-RM squat performance, agility, body composition (body fat percentage), or sport-specific measures.
7) lack of data

3.3 Quality Assessment

The "Physiotherapy Evidence Database Scale" (PEDro) was used to assess the overall quality of the included studies. Similar to Übellacker and Bauer (2017) three investigators completed the assessment process independently. For every fulfilled criterion the respective study received one point. Each intervention could reach a maximum of ten points.

4 Results

4.1 Selection Process

The search process in the mentioned data bases (see 3.1.) resulted in 12421 records. After the removal of 2,977 duplicates, 9,444 records remained for title and abstract screening. In this process 9,233 records were removed. The remaining 211 studies were examined in a full-text screen in which 170 studies were excluded as they did not meet the required inclusion criteria. Consequently, 41 studies were included in the systematic in-depth analysis (Figure 6).

4.2 Quality Assessment

Overall, a mean score of 3.34 out of 10 points was reached. The scores ranged between two and five points. The seemingly inferior quality, however, could be explained by the fact that some requirements are unlikely to be fulfilled in non-clinical interventions (e.g. "blinding of subjects", "received treatment as allocated", "blinding of therapist"). Two interventions (García-Pinillos, Martínez-Amat, Hita-Contreras, Martínez-López, & Latorre-Román, 2014; Torres-Torrelo, Rodríguez-Rosell, & González-Badillo, 2017) reached the highest score of 5 points.

Flow Chart

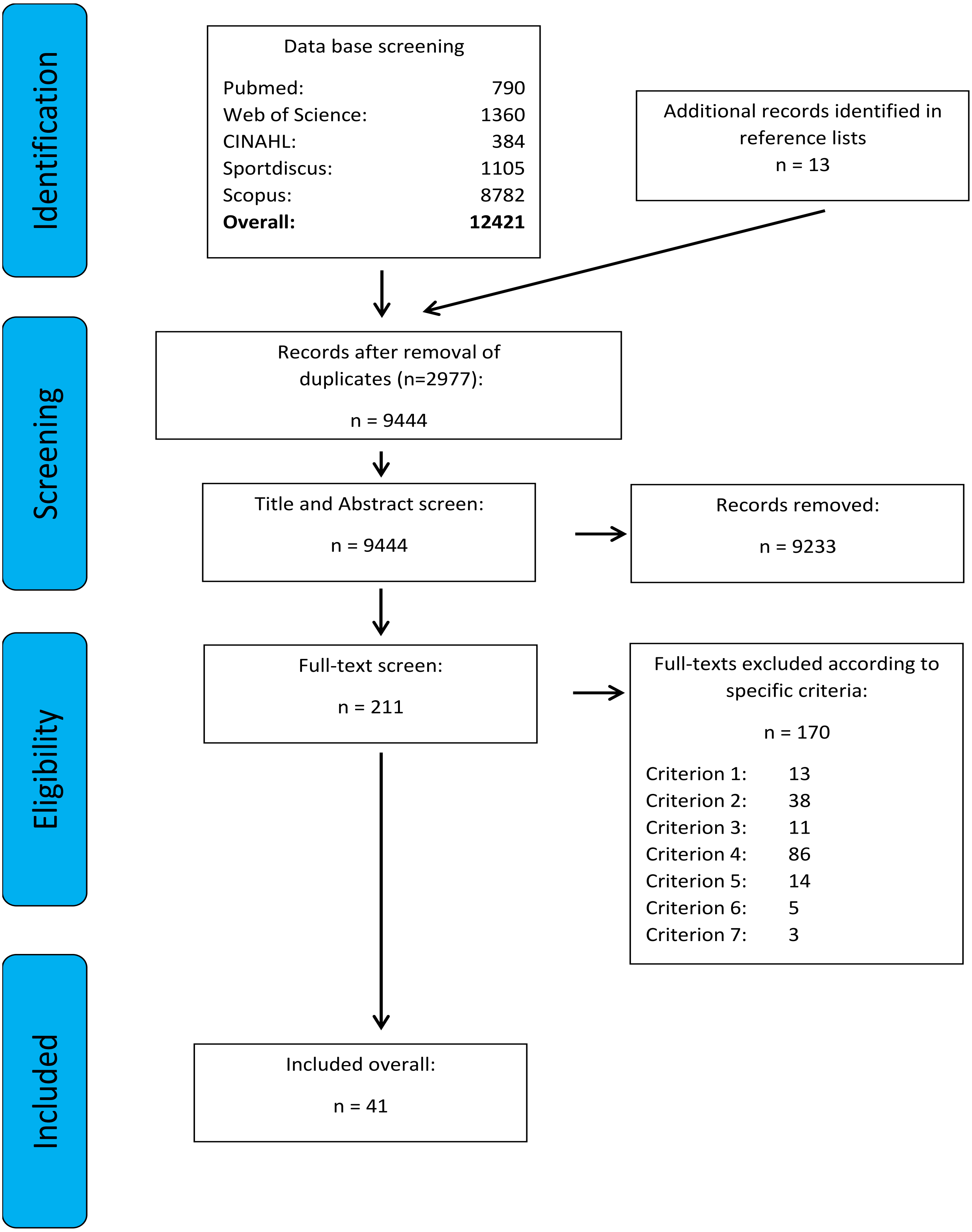

Figure 6: Flow Chart (Adapted from Moher, Liberati, Tetzlaff, and Altman (2009))

Table 4: PEDro criteria and sum scores of the included studies

Authors and year	Eligibility specified	Subjects randomly allocated	Concealed allocation	Similar baseline values	Blinding of subjects	Blinding of therapist	Blinding of assessor	Dropout < 15%	Received treatment as allocated	Statistical between group comparison	Point measures and variability provided	Sum (items 2 to 11)
Alemdaroglu et al. (2013)*	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
Arabatzi et al. (2010)*	0	1	0	0	0	0	0	0	0	1	1	3
Arazi et al. (2014)*	0	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 & Alvar (2007)*	0	1	0	0	0	0	0	0	0	1	1	3
Fathi et al. (2018)*	0	0	0	1	0	0	0	1	0	1	1	4
Faude et al. (2013)*	0	1	0	0	0	0	0	0	0	1	1	3
Fletcher & Hartwell (2004)	0	1	0	0	0	0	0	0	0	0	1	2
Franco-Marquez et al. (2015)*	0	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
Hammami et al. (2017a)*	0	1	0	1	0	0	0	0	0	1	1	4
Hammami et al. (2017b)*	0	1	0	0	0	0	0	0	0	1	1	3
Hammami et al. (2018)*	0	1	0	1	0	0	0	0	0	1	1	4
Juarez et al. (2009)*	0	1	0	1	0	0	1	0	0	0	1	4
Kamal (2016)	0	0	0	0	0	0	0	0	0	1	1	2
Kobal et al. (2017)*	0	1	0	1	0	0	0	0	0	1	1	4
Kotzamanidis et al. (2005)*	0	1	0	1	0	0	0	0	0	1	1	4
Kramer et al. (1993)	0	1	0	0	0	0	0	1	0	1	1	4
Kukric et al. (2012)*	0	0	0	1	0	0	0	0	0	1	1	3

Labib (2013)	0	0	0	0	0	0	0	0	0	1	1	2
Lee et al. (2014)	0	1	0	0	0	0	0	0	0	1	1	3
Lloyd et al. (2016)*	0	1	0	0	0	0	0	1	0	1	1	4
Loturco et al. (2014)	0	0	0	0	0	0	0	0	0	1	1	2
Lyttle et al. (1996)*	0	1	0	0	0	0	0	0	0	1	1	3
MacDonald et al. (2012)*	0	1	0	1	0	0	0	0	0	1	1	4
McMaster (2014)	0	0	0	0	0	0	0	0	0	0	1	1
Mihalik et al. (2008)*	0	1	0	0	0	0	0	0	0	1	1	3
Radnor et al. (2017)	0	1	0	0	0	0	0	0	0	1	1	3
Ronnestad et al. (2008)*	0	1	0	1	0	0	0	0	0	1	1	4
Rodriguez et al. (2017)	0	1	0	1	0	0	0	0	0	1	1	4
Smith et al. (2014)*	1	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
Talpey et al. (2016)*	0	1	0	1	0	0	0	0	0	1	1	4
Torres-Torrelo et al. (2017)*	0	1	0	1	0	0	0	1	0	1	1	5
Tsimachidis et al. (2010)*	0	1	0	1	0	0	0	0	0	1	0	3
Veliz et al. (2014)*	0	1	0	1	0	0	0	0	0	1	1	4
Veliz et al. (2015)*	0	1	0	1	0	0	0	0	0	1	1	4
Villareal et al. (2011)*	0	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
Wallenta et al. (2016)*	0	0	0	1	0	0	0	0	0	1	1	3

*** data received from Bauer et al. (in preparation for publication)**

4.3 Subject Characteristics

The examined studies vary considerably in their choice of subjects and their overall characteristics. The following section will cover these factors. The data are presented in Table 6.

4.3.1 Gender

Concerning the subjects' gender, 32 of the included studies tested male athletes only. In contrast, five studies only included female subjects (Arazi, Asadi, & Roohi, 2014; Kamal, 2016; Kramer et al., 1993; Labib, 2013; Veliz et al., 2015). Four interventions tested men and women; two did not specify the actual number (de Villarreal, Izquierdo, & Gonzalez-Badillo, 2011; Smith, Lyons, & Hannon, 2014), and two did (15m/9f; 11m/20f) (Alemdaroglu, Dündar, Köklü, Asci, & Findikoglu, 2013; Mihalik et al., 2008).

4.3.2 Age

Eleven of 41 studies included subjects with a mean age of 18 years or younger. Four of these included subjects between 14-16 years (Fathi et al., 2018; Franco-Márquez et al., 2015; García-Pinillos et al., 2014; Hammami et al., 2018). The other 30 interventions featured athletes over the age of 18. Of these 30, five interventions included subjects older than 24 years (mean) (Fletcher & Hartwell, 2004; Rodríguez-Rosell et al., 2017; Smith et al., 2014; Torres-Torrelo et al., 2017; Veliz et al., 2015). Overall, the ages ranged between 14.5 (± 0.6) (Fathi et al., 2018) and 29.0 (± 7.4) years (Fletcher & Hartwell, 2004).

4.3.3 Training Status

For operationalization purposes the subjects where allocated between four categories in this analysis: *pro level, intermediate or junior level, amateur level, or regularly active* or *untrained.*

Pro level:	subjects playing in a national first or second division / indicated as "professional" in the respective paper / special operations army soldiers
Intermediate or junior level:	subjects playing in a third or lower national/regional division or in a junior league/college team / being described as "very good", or experienced
Amateur level or regularly active:	healthy and regularly active subjects / sports students
Untrained:	no regular training

Among the 41 studies analyzed, ten tested subjects which show a training status that can be classified as *pro level*. Thirteen interventions included *intermediate or junior level* athletes. Subjects in the category *amateur level or regularly active* where tested in 17 interventions, and only a single study featured *untrained* subjects (Arazi et al., 2014) (Table 5).

Table 5: Training Status Categories

Pro level	Intermediate or junior level	Amateur level, or regularly active	Untrained
Alves et al. (2010)	Alemdaroglu et al. (2013)	Arabatzi et al. (2010)	Arazi et al. (2014)
Fathi et al. (2018)	Dodd & Alvar (2007)	Brito et al. (2014)	
Franco-Marquez et al. (2015)	Faude et al. (2013)	Hammami et al. (2017a)	
Kobal et al. (2017)	Fletcher & Hartwell (2004)	Juarez et al. (2009)	
Loturco et al. (2014)	Garcia-Pinillos et al. (2014)	Kamal (2016)	
Mihalik et al. (2008)	Hammami et al. (2017b)	Kotzamanidis et al. (2005)	
Ronnestad et al. (2008)	Hammami et al. (2018)	Kramer et al. (1993)	
Veliz et al. (2014)	Kukric et al. (2012)	Lee et al. (2014)	
Veliz et al. (2015)	Labib (2013)	Lloyd et al. (2016)	
Wallenta et al. (2016)	Lyttle et al. (1996)	MacDonald et al. (2012)	
	Rodriguez et al. (2017)	McMaster (2014)	
	Torres-Torrelo et al. (2017)	Radnor et al. (2017)	
	Tsimachidis et al. (2010)	Smith et al. (2014)	
		Stasinaki et al. (2015)	
		Talpey et al. (2016)	
		Villareal et al. (2011)	
		Villareal et al. (2013)	

4.3.4 Number of Subjects

Overall, the 41 selected studies included 1354 subjects, with a mean of 33 subjects per intervention. The lowest number of subjects (11) was tested by Fletcher and Hartwell (2004), whereas de Villarreal et al. (2011) recorded the highest number (65). The majority of interventions (32) tested men only, resulting in a total of 1112 male subjects. On the contrary, five interventions tested only women (Arazi et al., 2014; Kamal, 2016; Kramer et al., 1993; Labib, 2013; Veliz et al., 2015). Together with the two studies which tested both men and women (Alemdaroglu et al., 2013; Mihalik et al., 2008) a total of 149 female subjects were included. These numbers do not include the participants tested by Smith et al. (2014) and (de Villarreal et al., 2011) (93 overall) as they tested both genders, but did not indicate the exact number.

4.4 Study Design

The interventions under review followed a variety of training protocols, showed varying durations and diverse training frequencies per week. The following section is going to cover these aspects.

4.4.1 Duration and Frequency

According to the in- and exclusion criteria (see 3.23.2) only studies which lasted longer than four weeks and feature one complex training group with a frequency of at least eight sessions where included in this thesis. The durations, therefore, ranged from four weeks (Dodd & Alvar, 2007; Mihalik et al., 2008) up to 16 weeks (Fathi et al., 2018; Veliz et al., 2014; Veliz et al., 2015). The average intervention duration was 8.17 weeks.

Concerning the training frequency, the interventions featured between six (Alves, Rebelo, Abrantes, & Sampaio, 2010) and 40 training sessions (McMaster, Gill, McGuigan, & Cronin, 2014) over the period of the respective studies. Although the frequency of six sessions would not meet the inclusion criteria, Alves et al. 2010 also included a CT group with a frequency of twelve session, and was, therefore, included in this analysis. Overall, 14 interventions had a training frequency lower than 16, whereas 27 studies showed a higher value.

4.4.2 Training Protocols

For better operationalization, the different training regimes are categorized according to Table 3 (see also 2.4.1). The category *complex training* includes: *Traditional Complex Training (CT), Block Set Complex Training (BS), Block Complex Training (BC).* The *alternative training* category includes: *Olympic Style Weight Training (OLY), Plyometric Training (PLYO),* and *Resistance Training (RT).* Non-experimental, non-training control groups are referred to as *Control Group (CTRL).* Training methods combining similar exercises as in complex training, but in a reverse order or on separate days are referred to as *alternative periodization models,* such as: *Reverse Complex Training (RCT), Reverse Block Complex Training (RBC), Reverse Block Set Complex Training (RBS), Compound Training (Comp),* and *Block-wise Periodization (BLOCK).*

Among the 41 studies under review 17 included a traditional complex training protocol (CT). 21 interventions compared some form of complex training to an alternative training method (RT, PLYO, OLY) and five featured an alternative periodization model (Comp, BLOCK) (Arazi et al., 2014; Juárez, González-Ravé, & Navarro, 2009; Mihalik et al., 2008; Stasinaki et al., 2015; Wallenta, Granacher, Lesinski, Schünemann, & Muehlbauer, 2016). 26 studies compared their complex training group(s) to a non-training control group, of which 13 studies (Alves et al., 2010; Faude, Roth, Di Giovine, Zahner, & Donath, 2013; Fletcher & Hartwell, 2004; Franco-Márquez et al., 2015; García-Pinillos et al., 2014; Hammami et al., 2017a; Kamal, 2016; Labib, 2013; Lee et al., 2014; Smith et al., 2014; Tsimahidis et al., 2010; Veliz et al., 2014; Veliz et al., 2015) compared to such a control group only. Two of these, however, featured two slightly different CT-groups to be compared to controls (Alves et al., 2010; Smith et al., 2014). Ten studies compared to alternative training methods only (Alemdaroglu et al., 2013; Arabatzi, Kellis, & Saez-Saez De Villarreal, 2010; de Villarreal et al., 2011; de Villarreal, Requena, Izquierdo, & Gonzalez-Badillo, 2013; Dodd & Alvar, 2007; Kobal et al., 2017; Kramer et al., 1993; MacDonald et al., 2012; McMaster et al., 2014; Talpey, Young, & Saunders, 2016)

4.4.3 Intensities and Exercise Selection

The intensities for the conditioning activities ranged from 30% in some sessions of the intervention (Loturco et al., 2014) to 95% (Kotzamanidis, Chatzopoulos, Michailidis, Papaiakovou, & Patikas, 2005; Lee et al., 2014; Radnor, Lloyd, & Oliver, 2017) or even 99% or 100% 1RM (Alves et al., 2010; McMaster et al., 2014)

Some studies, however, used loads below 60% of the 1RM (Faude et al., 2013; Franco-Márquez et al., 2015; MacDonald et al., 2012; Torres-Torrelo et al., 2017). Others relied on different measures for intensity prescription, such as velocity-based measurements (Veliz et al., 2014; Veliz et al., 2015) or the “MP = weight [with] which the maximal power in CMJ_{loaded} is obtained” – for example “MP + 10%” - (de Villarreal et al., 2011; de Villarreal et al., 2013). Furthermore, Rodríguez-Rosell et al. (2017) relied a force system to assign the loads, whereas García-Pinillos et al. (2014) used isometric CAs preceding the plyometric exercises.

Concerning the exercises, the most frequent conditioning activities were full squats, half squats, back squats with and without the use of a smith machine. Further, many studies included some form of lunges in their training protocols (Arazi et al., 2014; Dodd & Alvar, 2007; Kamal, 2016; Labib, 2013; Lloyd, Radnor, Croix, Cronin, & Oliver, 2016; Radnor et al., 2017). For the plyometrics part in the CT protocols, most studies included countermovement jumps, squat jumps or drop jumps. Some protocols featured agility-based exercised, such as zigzag drills or change of direction drills (Alves et al., 2010; Arazi et al., 2014; Faude et al., 2013). Several studies used sprints only (Kotzamanidis et al., 2005; Tsimahidis et al., 2010) or a combination of sprints and jumps in their training programs (Brito, Vasconcellos, Oliveira, Krustrup, & Rebelo, 2014; Hammami et al., 2017a; Hammami, Negra, Shephard, & Chelly, 2017b; Juárez et al., 2009; Wallenta et al., 2016).

4.4.4 Rest Periods for CT-Groups

Overall, 24 studies indicate the inter- and/or intra-complex rest periods for their complex training groups. 17 studies do neither mention inter- nor intra-complex rest in their CT-protocols. The intra-complex rest ranges from “>10 seconds” in Dodd and Alvar (2007) up to 3-5 (Juárez et al., 2009) or 4 minutes (Talpey et al., 2016). The inter-complex rest ranges from 0,5 – 2 minutes (Smith et al., 2014) to 3-5 or 5 minutes respectively (Juárez et al., 2009; Stasinaki et al., 2015). Overall, the studies which indicate the rest periods show a mean of 2.17 minutes as intra-complex and 3.03 minutes as inter-complex rest.

Table 6: Results

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
Alemdaroglu et al. (2013)*	8 (5m/ 3f)	recreationally trained, experience in resistance and plyometric training	19,2 - 24,5	6/2	Alt. P.	RBS	split squats, leg press, leg curls	3/6/ 85-90%	split jumps, squat jumps, front tuck jumps	3/8/-		CMJ male: RBS: 7.32** BS: 8.52* CT: 7.71** CMJ female: RBS: 26.76** BS: 1.77** CT: 13.75** SJ male: RBS: 8.06** BS: 4.94** CT: 9.68** SJ female: RBS: 29.47** BS: 4.55** CT: 9.52**
	8 (5m/ 3f)		19,2 - 24,5	6/2	Complex	BS	split squats, leg press, leg curls	3/6/ 85-90%	split jumps, squat jumps, front tuck jumps	3/8/-		
	8 (5m/ 3f)		19,2 - 24,5	6/2	Complex	CT	split squats, leg press, leg curls	3/6/ 85-90%	split jumps, squat jumps, front tuck jumps	3/8/-	1 intra-complex; 2 inter-complex	
Alves et al. (2010)*	9 (m)	elite Portuguese soccer players	17.4 ± 0.6	6/1	Complex	CT	squat 90°, calf extensions.; leg extensions	3/6/ 80-100%	5m skipping+5m sprint; 8VJ+3 ball headers; 3 DJ with headers	-	n.i.	5m sprint: CT: -9.17**, + to CTRL CT: -6.19*, + to CTRL CTRL: -1.77 15m sprint: CT: -7.03**, + to CTRL CT: 0.78* CTRL: -1.16 SJ: CT: 12.60**, + to CTRL CT: 9.63*, + to CTRL CTRL: -0.73 CMJ CT: 0.19 CT: 2.42 CTRL: -2.58 505 Agility test: CT: -1.28
	8 (m)		17.4 ± 0.6	6/2	Complex	CT	squat 90°, calf extensions, leg extensions	3/6/ 80-100%	5m skipping+5m sprint; 8VJ+3 ball headers; 3 DJ with headers	-	n.i.	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	6 (m)		17,4 ± 0,6	6/2	Control	CTRL	-	-	-	-	-	CT: 0.00 CTRL: 0.84
Arabatzi et al. (2010)*	10 (m)	sport students	20,3 ± 2	8/3	Complex	BC	power cleans, snatch, clean and jerk, high pulls, half squats	4-6/ 4-6/ 75-90%	double-leg hurdle hops, alternated single-leg hurdle hops, double-leg hops, half-squats	4-6/ 4-6/ -	3 between sets	CMJ: BC: 15.12*, + to CTRL OLY: 15.03*, + to CTRL PLYO: 14.60*, + to CTRL CTRL: 5.71 SJ BC: 15.12*, + to CTRL OLY: 15.03*, + to CTRL PLYO: 14.60*, + to CTRL CTRL: 5.71
	9 (m)		20.3 ± 2	8/3	Alt. Tr.	OLY	power cleans, snatch, clean and jerk, high pulls, half squats	4-6/ 4-6/ 75-90%	-	-	-	
	9 (m)		20.3 ± 2	8/3	Alt. Tr.	PLYO	-	-	double-leg hurdle hops, alternated single-leg hurdle hops, double-leg hops, half-squats	4-6/ 4-6/ -	-	
	8 (m)		20.3 ± 2	8/3	Control	CTRL	-	-	-	-	-	
Arazi et al. (2014)*	8 (f))	healthy untrained women	20.8 ± 0.7	6/2	Alt. Tr.	PLYO	-	-	depth jumps, multiple jumps, zigzag drill, lunge jumps	6/6	-	1RM leg press: PLYO: 44.26* RT: 48.86* Comp: 40.18* CT: 37.62* CMJ: PLYO: 19.32* RT: 20.03* Comp: 28.31*
	7 (f)		20.7 ± 1.1	6/2	Alt. Tr.	RT	half squats, knee extensions, knee flexions, single-leg lunges	6/6/ 60%	-	-	-	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	7 (f)		20.7 ± 0.7	6/2	Alt. P.	Comp	half squats, knee extensions, knee flexions, single-leg lunges	6/6/ 60%	depth jumps, multiple jumps, zigzag drills, lunge jumps	6/6	1 between ex.	CT: 17.34* 20m sprint: PLYO: -15.66* RT: -7.19* Comp: -15.66* CT: -9.73*
	7 (f)		20.6 ± 0.5	6/2	Complex	CT	half squats, knee extensions, knee flexions, single-leg lunges	3/6/ 60%	depth jumps, multiple jumps, zigzag drills, lunge jumps	3/6	1 between ex.	Agility t-test: PLYO: -7.65* RT: -6.28* Comp: -7.88* CT: -3.25*
Brito et al. (2014)*	12 (m)	college students engaged in different local soccer clubs	20.3 ± 0.9	9/3	Alt. Tr.	RT	squats, calf extensions, leg extensions	1/6/ 80-90%	-	-	n.i.	1RM Squat: RT: 22.79***, +++ to CTRL PLYO: 17.32***, +++ to CTRL CT: 24.17***, +++ to CTRL CTRL: 2.38 20m sprint: RT: -5.33***, +++ to CTRL PLYO: -4.70***, +++ to CTRL CT: -6.15***, +++ to CTRL CTRL: -1.25
	12 (m)		20.0 ± 0.6	9/3	Alt. Tr.	PLYO	-	-	skipping 5m, 5m sprint, 8 CMJ, ball headers, 6 SJ, 3 DJ	1/3-8	n.i.	
	12 (m)		19.9 ± 0.5	9/3	Complex	CT	squats, calf extensions, leg extensions	1/6/80-90%	skipping 5m, 5m sprint, 8 CMJ, ball headers, 6 SJ, 3 DJ	1/3-8	n.i.	
	21 (m)		20.7 ± 1	9/3	Control	CTRL	-	-	-	-	n.i.	
Dodd & Alvar (2007)*	32 (m)	division II junior college baseball players with at least 1 year of strength	18-23	4/2	Complex	CT	squats, lunges, split squats	2/6/80-90%	box jumps, depth jumps, split squat jumps	2/6/-	>10 sec intra-complex; 3-4 inter-complex	20m sprint: CT: -0.55 RT: 0.49 PLYO: -0.14 40m sprint: CT: -0.26 RT: 0.71 PLYO: 1.35

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	31 (m)	training experience	18-23	4/2	Alt. Tr.	RT	squats, lunges, split squats	4/6/80-90%	-	-	-	60m sprint: CT: -0.28 RT: -0.15 PLYO: 0.28 CMJ: CT: 0.99 RT: 0.36 PLYO: 1.91 Agility t-test: CT: -2.33 RT: -1.24 PLYO: 0.04
	28 (m)		18-23	4/2	Alt. Tr.	PLYO	-	-	box jumps, depth jumps, split squat jumps	4/6/-	-	
Fathi et al. (2018)*	20 (m)	first division Tunisian volleyball club player	14.7± 0.6	16/2	Complex	BC	half squats, Bulgarian split squats, bench press, behind the neck press	1-2/8-12/ 40-70%	hurdle jumps, drop jumps	2-3/6-8/-	n.i.	SJ: BC: 7.24*** PLYO: 4.08* CTRL: -1.34 CMJ: BC: 6.15***, +++ to PLYO PLYO: 3.37*** CTRL: 0.62 5m sprint: BC: 6.47*** PLYO: 4.35* CTRL: 0.00 10m sprint: BC: 3.47*** PLYO: 2.39* CTRL: 0.00 Body Fat %: BC: -7.80**, ++ to CTRL PLYO: -7.54**, ++ to CTRL CTRL: 1.56
	20 (m)		14.6 ± 0.5	16/2	Alt. Tr.	PLYO	-	-	hurdle jumps, drop jumps	3-5/8-10/-	-	
	20 (m)		14.5 ± 0.6	16/0	Control	CTRL	-	-	-	-	-	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
Faude et al. (2013)*	8 (m)	soccer players in the third Swiss league	22.6 ± 2.4	7/2	Complex	CT	2 different training regimes (alternated). session 1: unilateral loaded half squats + 1 plyo. session 2: (2 of the following combined with 2 plyo): loaded half squats, loaded calf raises, loaded lateral half squats, loaded step-ups	3-4/4-5/ 50-90%	single-leg hurdle jumps, DJ, 5m sprint, high straight jumps, lateral jumps, zig zag sprints, bounding jumps, headers	2-4/5-8	Session 1: 4 inter-complex Session 2: 1-2 inter- & intra complex	1RM Squat: CT: 18.22***, +++ to CTRL CTRL: 0.66 CMJ: CT: 2.99+++ to CTRL CTRL: -7.44 DJ: CT: 5.57 CTRL: -3.64 10m sprint: CT: 0.00 CTRL: 2.31 30m sprint: CT: 0.23 CTRL: 1.70 Agility t-test: CT: -4.08* CTRL: -2.11
	8 (m)		23.1 ± 2.7	7/2	Control	CTRL	-	-	-	-	-	
Fletcher & Hartwell (2004)	6 (m)	very good club standard male golfers	29.0 ± 4.7	8/2	Complex	BC	bench press, squats, single arm rows, lunges, shoulder press, upright rows, abdominal crunches, back extensions, side bends	3-6/6-8/ 80-85%	(medicine ball 3kg) seated horizontal twists, standing horizontal twists, standing back, extensions, golf swings	3/8	n.i.	Club head speed: BC: 1.50* CTRL: 0.50 Driving distance BC 4.30* CTRL: -0.70
	5 (m)		29.0 ± 4.7	8/0	Control	CTRL	-	-	-	-	-	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
Franco-Marquez et al. (2015)*	18 (m)	male soccer players, Spanish first division, no strength training experience	14.7 ± 0.5	6/2	Complex	BC	squats	4-8/2-3/ 45-58%	CMJ, step phase triple jumps, change of direction, sprint	3-8/2	3 intra- & 3 inter-complex	10m sprint: BC: -1.14 CTRL: 0.00 20m sprint: BC: -0.97* CTRL: 0.00 CMJ: BC: 9.04*** CTRL: 0.60 1RM: BC: 28.83*** CTRL: 2.34
	18 (m)		14.7 ± 0.5	6/0	Control	CTRL	-	-	-	-	-	
Garcia-Pinillos et al. (2014)*	17 (m)	semi-professional soccer academy players	15.5 ± 1.3	12/2	Complex	CT	isometric 90° squat	4-10/40sec/-	jumps from seated position, single-leg jumps alternated right and left	4-10/6/-	n.i.	5m sprint: CT: -14.97*** CTRL: -12.05*** 10m sprint: CT: -13.36*** CTRL: -7.44 20m sprint: CT: -8.36***, + to CTRL CTRL: -5.61* 30m sprint: CT: -6.26***, + to CTRL CTRL: -3.83* CMJ: CT: 7.14*** CTRL: 2.22 Balsom Agility Test: CT: -5.13***, + to CTRL CTRL: -0.34
	13 (m)		16.4 ± 1.5	12/0	Control	CTRL	-	-	-	-	-	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
Hammami et al. (2017a)*	16 (m)	all players had previously undergone strength training with light loads from an early age	16.2 ± 0.6	6/2	Complex	CT	back squats; ascending / descending sets; 3x8 at 70%; 5x4 at 80%; 4x3 at 85%; 3x3 at 90%	3-5/3-8/ 70-90%	week 1-4: CMJ; week 5-8: CMJ + 15m sprint	1/3/-	n.i.	5m sprint CT: -11.40***, +++ to CTRL RT: -9.82***, +++ to CTRL CTRL: -2.61 10m sprint CT: -7.49**, ++ to CTRL RT: -8.42**, ++ to CTRL CTRL: -1.04 20m sprint CT: -8.43**, ++ to CTRL RT: -5.54***, +++ to CTRL CTRL: 0.00 30m sprint: CT: -7.44**, ++ to CTRL RT: -7.21**, ++ to CTRL CTRL: -0.65 40m sprint: CT: -9.06**, ++ to CTRL RT: -5.94*, + to CTRL CTRL: -1.52 Agility S180°: CT: -5.26***, +++ to CTRL RT: -3.46*, + to CTRL CTRL: -0.12 Agility 4x5m: CT: -7.17***, +++ to CTRL RT: -2.25*, + to CTRL CTRL: -0.48 Agility back and forward: CT: -4.95***, +++ to CTRL RT: -4.22*, + to CTRL CTRL: -0.59 1RM Squat: CT: 41.02***, +++ to CTRL RT: 23.94***, +++ to CTRL CTRL: 6.07 RCOD: CT: -5.58***, +++ to CTRL
	16 (m)		16.0 ± 0.5	6/2	Alt. Tr.	RT	back squats; session 1 descending / session 2 descending sets; 3x8 at 70%; 5x4 at 80%; 4x3 at 85%; 3x3 at 90%	3-5/3-8/ 70-90%	-	-	n.i.	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	12 (m)		16.8 ± 0.2	6/0	Control	CTRL	-	-	-	-	-	RT: -5.18***, +++ to CTRL CTRL: -0.03 SJ: CT: 23.37***, +++ to CTRL RT: 11.23***, +++ to CTRL CTRL: -3.11 CMJ: CT: 25.26***, +++ to CTRL RT: 12.66**, ++ to CTRL CTRL: -2.43
Hammami et al. (2017b)*	17 (m)	U17 pro soccer team	16.0 ± 0.5	8/2	Complex	CT	half squats	3-5/3-8/ 70-90%	week 1-4: CMJ; week 5-8: CMJ + 15m sprint	1/3/-	n.i.	5m sprint: CT: -11.40*** CTRL: 4.72 10m sprint: CT: -7.85** CTRL: 1.60 20m sprint: CT: -7.88** CTRL: 1.87 30m sprint: CT: -7.24** CTRL: 1.11 40m sprint: CT: -8.43** CTRL: -1.53 1RM Squat: CT: 43.16*** CTRL: 5.32 180° turn sprint: CT: -5.14** CTRL: 0.12 Back and forward sprint: CT: -4.38* CTRL: 0.81 4x5m sprint: CT: -6.41** CTRL: -0.81
	12 (m)	U17 pro soccer team	16.8 ± 0.2	8/0	Control	CTRL	-	-	-	-	-	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
Hammami et al. (2018)*	14 (m)	junior elite level	16.1 ± 0.5	8/2	Complex	CT	half squats	3-5/3-8/ 70-90%	week 1-4: CMJ; week 5-8: CMJ + 15m sprint	1/3/-	n.i.	5m sprint: CT: -10.62*** PLYO: -7.41*** CTRL: 4.85 40m sprint: CT: -8.43*** PLYO: -3.48** CTRL: -1.71 CMJ: CT: 23.04***, ++ to Alt. Tr. PLYO: 14.09*** CTRL: -1.85 1RM Squat: CT: 46.42*, + to PLYO. CTRL PLYO: 9.18 CTRL: 6.38 4x5m sprint: CT: -6.72** PLYO: -3.36** CTRL: 0.98
	14 (m)		15.7 ± 0.2	8/2	Alt. Tr.	PLYO	-	-	hurdle jumps, drop jumps		n.i.	
	12 (m)		15.8 ± 0.2	8/0	Control	CTRL	-	-	-	-	-	
Juarez et al. (2009)*	8 (m)	sport students, habitually active (5–6 hours per week – moderate volume and intensity running) but not	19.3 ± 1.4	8/2	Complex	BC	squats	2-3/4-8/ 70-85%	vertical jumps, hurdle jumps, drop jumps, bench jumps, 20m sprint	2-3/2-5/-	3-5 inter- & intra-complex	1RM Squat: BC: 9.86** BLOCK: 8.73** SJ: BC: 11.49** BLOCK: 12.30** CMJ: BC: 11.76** BLOCK: 5.42 5m sprint: BC: -6.03*

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	8 (m)	specifically strength trained	20.0 ± 1.9	8/2	Alt. P.	BLOCK	squats	2-3/4-8/ 70-85%	vertical jumps, hurdle jumps, drop jumps, bench jumps, 20m sprint	2-3/2-5/-	3-5	BLOCK: 5.56* 10m sprint: BC: -3.77* BLOCK: -3.43* 15m sprint: BC: -2.95* BLOCK: 2.33 20m sprint: BC: -2.92* BLOCK: -2.33
Kamal (2016)	10 (f)	female karate athletes	18	8/0	Control	CTRL	-	-	-	-	-	Composit Skillful Performance: CTRL: -1.75 BS: -10.53*
	10 (f)		18	8/3	Complex	BS	1. squat, 2. bench press, 3. barbell lunge, 4. lat pull down, 5. abdominal crunches, 6. decline press	3/12/ 70-75%	1a. vertical jumps, 2a. medicine ball chest pass, 3a. step jumps, 4a. medicine ball overhead pass, 5a. medicine ball sit up and throw, 6a. zigzag drill	3/10/-	60/90 between sets. ; 3 min between exercises	
Kobal et al. (2017)*	12 (m)	elite soccer players; first division championship; no experience in strength	18.9 ± 0.6	8/2	Complex	RBS	half squats	3-5/6-10/ 60-80%	DJ 30-45cm	3-5/10-12	3 inter- & intra-complex	CMJ: RBS: 13.26* BS: 14.29* CT: 14.78* Squat: RBS: 47.25* BS: 45.25*
	13 (m)		18.9 ± 0.6	8/2	Complex	BS	half squats	3-5/6-10/ 60-80%	DJ 30-45cm	3-5/10-12	3 inter- & intra-complex	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	13 (m)	and plyometric training	18.9 ± 0.6	8/2	Complex	CT	half squats	3-5/6-10/ 60-80%	DJ 30-45cm	3-5/10-12	3 inter- & intra-complex	CT: 52.75*
Kotzamanidis et al. (2005)*	12 (m)	healthy Soccer players; 4 years of training age and Tanner Stage 5	17.0 ± 1.1	9/2	Complex	BC	half squats, step-ups, leg curls	4/3-8/ 80-95%	sprint 30m		3 between sets	1RM Squat: BC: 8.65**, ++ to CTRL RT: 10.03**, ++ to CTRL CTRL: 1.50 SJ: BC: 7.80**, ++ to RT &CTRL RT: 1.87 CTRL: 1.01 CMJ: BC: 6.68**, ++ to RT & CTRL RT: 0.88* CTRL: -0.21 DJ: BC: 5.53** RT: 2.61* CTRL: 3.34 30m sprint: BC: -3.46**, ++ to RT & CTRL RT: -0.46 CTRL: -0.44
	11 (m)		17.1 ± 1.1	9/2	Alt. Tr.	RT	n.i.	3-8RM	-			
	12 (m)	random sport science students; without sport training backgrounds, moderately active	17.8 ± 0.3	9/0	Control	CTRL	-	-	-			
Kramer et al. (1993)	11 (f)	female rowers	18-22	9/3	Alt. Tr.	RT	clean pulls, half squats, bench pulls, leg press, seated rows	4-10/5-20/80%	-	-	n.i.	Time (s) to row 2500m: RT: -3.04** BC: -3.46** Distance (m) rowed in 90 s: RT: 3.556**

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	13 (f)		18-24	9/3	Complex	BC	clean pulls, half squats, bench pulls, leg press, seated rows	4-10/5-20/80%	squat jumps, stair jumps, jump over bench, drop jumps (30 cm)	1-10/5-20	n.i.	BC: 4.08** CMJ: RT: 5.61** BC: 5.56**
Kukric et al. (2012)*	10 (m)	junior basketball players. 7 years of basketball experience	16-17	10/2	Complex	BS	calf raises, leg press, half squats	3/3-5/80%	alternating jumps on one leg, jump over hurdle 50cm, telemark jumps, jumps over hurdle	3/8	n.i.	CMJ: BS: 13.75* PLYO: 10.46* CTRL: 0.54
	10 (m)		16-17	10/2	Alt. Tr.	PLYO	-	-	SJ, hurdle jumps, one leg push, box jumps, DJ 50cm, alternating jumps on one leg,	3/10		
	10 (m)		16-17	-	Control	CTRL	-	-	-			
Labib (2013)	10 (f)	female handball players (faculty of PE handball	18-22	8/0	Control	CTRL						Jump Shot Performance: CTRL: 7.47 BS: -17.62*

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	10 (f)	team Helwan University)	18-22	8/3	Complex	BS	1. squats, 2. bench press, 3. barbell lunges, 4. lat pull downs, 5. abdominal crunches, 6. decline press	3/12/70-75%	1a. vertical jumps, 2a. medicine ball chest pass, 3a. step jumps, 4a. medicine balloverhead pass, 5a. medicine ball sit up and throw, 6a. zigzag drill	3/10/-	60/90 between sets. ; 3 min between exercise	
Lee et al. (2014)	10 (m)	ice hockey players, (no further description)	18-22	12/0	Control	CTRL						5x18m shuttle: CTRL: 2.01 BS: -8.82***, +++ to CTRL t-test: CTRL: 2.87 BS: -17.20***, +++ to CTRL Rink dash 5 times: CTRL: 0.03 BS: -6.60***, +++ to CTRL Line drill: CTRL: -7.41*** BS: -9.37***, + to CTRL
	10 (m)		18-22	12/3	Complex	BS	upper body: 1. bench press 2. biceps curl 3. lying triceps extensions 4. crunches 5. lat pull down; lower body: 1. back squats 2. leg curls 3. leg extensions 4. standing calf raises 5. hip sled	3-5/2-12 /70-95%	upper body: 1-a. chest pass 2-b. depth push-up 3-c. two hand overhead throws, 4-d. sit-up pass, 5-e. two hand side throws lower body: 1-a. squat jumps 2-b. tuck jumps 3-c. pike jumps 4-d. depth jumps, 5-e. double-leg zigzag hops	3-5/10-15/-	2-3 inter- & intra-complex	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
Lloyd et al. (2016)*	10 (m)	School Kids. All participants had previously been engaged in physical education–based activities; not involved in any formalized strength program	16.2 ± 0.3	6/2	Complex	CT	back squats, lunges	3/10/70-75%	“different exercises but no upper body and sprint”	2-5/3-10/-	1-2 inter- & intra-complex	10m sprint: CT: -5.26** RT: 5.26* PLYO: 0.00 CTRL: 0.00 20m sprint: CT: -7.14* RT: -3.57 PLYO: -3.70** CTRL: 0.00 SJ: CT: 12.65** RT: 6.79** PLYO: 1.24 CTRL: 0.00
	10 (m)		16.3 ± 0.3	6/2	Alt. Tr.	RT	back squats, lunges	3/10/70-75%				
	10 (m)		16.2 ± 0.2	6/2	Alt. Tr.	PLYO			drop landings, VJ in place, horizontal jumps, drop landings, pogo hopping, bilateral rebounds, hurdles, unilateral horizontal jumps	2-5/3-10		
	10 (m)		16.2 ± 0.3	6/2	Control	CTRL						
Loturco et al. (2014)	18 (m)	male soldiers of the Brazilian special operations brigade with a minimum of one year army training	20.1 ± 0.7	9/3	Alt. Tr.	RT	smith machine squats, loaded jump squats, CMJ	3/4-6/30-80%			-	20m sprint: RT: 16*,+ to CTRL BS: 14*,+ to CTRL CTRL: n.i. 1RM smith machine squat: RT: 25*,+ to CTRL BS: 26*,+ to CTRL CTRL: n.i. CMJ: RT: 36*,+ to CTRL BS: 39*,+ to CTRL CTRL: n.i.
	15 (m)		20.3 ± 0.8	9/3	Complex	BS	smith machine squats	1/4-8/30-80%	loaded jump squats, CMJ	1/4-8/-	n.i.	
	15 (m)		20.2 ± 0.7	9/0	Control	CTRL	-	-	-	-	-	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
Lyttle et al. (1996)*	11 (m)	regional level sports; no specific strength or plyometric training during the previous year	23.8 ± 5.4	8/2	Complex	BC	squats 80-180°	1-2/6-10/80-85%	depth jumps	1-2/0.20 - 0.60cm	n.i.	1RM Squat: BC: 14.56*, + to CTRL PLYO: 14.16*, + to CTRL CTRL: 2.67 CMJ: BC: 10.61*, + to CTRL PLYO: 7.48*, + to CTRL CTRL: 0.00 40m sprint: BC: -0.73 PLYO: 1.28 CTRL: -0.54 SJ: BC: 16.58*, + to CTRL PLYO: 18.35*, + to CTRL CTRL: 0.55
	11 (m)		23.9 ± 6.4	8/2	Alt. Tr.	PLYO	-	-	squat jumps	2-6/8/-	n.i.	
	11 (m)		20.6 ± 3.4	8/0	Control	CTRL	-	-	-	-	n.i.	
MacDonald et al. (2012)*	10 (m)	recreationally trained college students	21.7 ± 3.4	6/2	Complex	CT	smith machine squats; Romanian dead lift; calf raise	3/3-6/45-90	lateral jumps, DJ 12-in up 18in; box jump double to single-leg	3/3-6/-	0.5 intra-complex with lighter loads, 3 with heavier loads	Squat: CT: 51.30* RT: 44.95* PLYO: 29.94* Body fat %: CT: 5.00 RT: 15.79* PLYO: 15.79*
	11 (m)		21.7 ± 3.4	6/2	Alt. Tr.	RT	smith machine squats; Romanian dead lift; calf raise	3/3-6/45-90	-	-	3	
	9 (m)		21.7 ± 3.4	6/2	Alt. Tr.	PLYO	-	-	lateral jump, DJ 12-in up 18in; box jump double to single-leg	3/3-6/-	3	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
McMaster (2014)	14(6/8) (m)	male provincial rugby union players	20.9 ± 1.6	10/4	Alt. Tr.	RT	back squats, Bulgarian split squats, incline dumbbell press, hip thrusts, calf raises, power cleans, 1 arm jammer press, bench press, weighted chin ups, 1 arm dumbbell floor press, 1 arm dumbbell rows	4-8/2-6/ 85-99%	high load ballistic exercises	4-5/2-4	3	1RM Squat: RT: 11.70* CT: 9.20* 10m sprint: RT: -1.20 CT: -1.60* 20m sprint: RT: -1.20* CT: -1.00* 30m sprint: RT: -0.60 CT: -0.90* CMJ Peak Power: RT: 46.20* CT: 35.60*
	14(6/8)(m)		20.9 ± 1.6	10/4	Complex	CT	-:-	4-9/2-7/ 85-99%	CMJ, cm bench press throws, 1 arm dumbbell snatch, concentric only bench throws, high pulls, 1/4 squat jump, speed lunge, alternate arm dumbbell bench press, box squat	5-8/5-8	3 inter- & intra-complex	
Mihalik et al. (2008)*	15 (5m, 10f)	divison I volleyball players	20.3 ± 2.2	4/2	Complex	BS	squats; single-leg lunges; deadlifts	3/6/85%	DJ, split SJ, double-leg bound	3/6	1 intra-complex, 2 inter-complex	CMJ: BS: 5.6*** Comp: 10.04***
	16 (6m, 10f)		20.9 ± 2.4.	4/2	Alt. P.	Comp	squats; single-leg lunges; deadlift	6/6/85%	DJ, split SJ, double-leg bound	3/6		

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
Radnor et al. (2017)	10 (m)	male school children, previously engaged in PE-based activities	16.4 ± 0.2	6/2	Alt. Tr.	PLYO	-	-	drop lands, broad jumps, single-leg forward hop and stick, split squat drop land, pogo hopping, multiple bilateral bouts. power skipping, etc.	2-5/3-10	n.i.	10m sprint: PLYO: 0.37 RT: 1.78*, + to PLYO, CTRL BS: 2.68*, + to PLYO, CTRL CTRL: 0.15 SJ: PLYO: 1.41 RT: 7.68*, + to PLYO, CTRL BS: 12.93*, + to PLYO, CTRL CTRL: -0.01
	10 (m)		16.3 ± 0.3	6/2	Alt. Tr.	RT	back squats, barbell lunges, dumbbell step-ups, leg press	3/10/75-95%	-	-		
	10 (m)		16.2 ± 0.3	6/2	Complex	BS	back squats, barbell lunges, dumbbell step-ups, leg press	3/10/75-80%	drop lands, broad jump, single-leg forward hop and stick, split squat drop land, pogo hopping, multiple bilateral bouts. power skipping, etc.	2-5/3-10		
	10 (m)		16.3 ± 0.3	6/0	Control	CTRL	-	-	-	-		

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
Ronnestad et al. (2008)*	8 (m)	Norwegian professional soccer players (Premier League); all subjects had experience with strength training	23.0 ± 2	7/2	Complex	BC	half squats; hip flexion	2-5/4-6/ 85-90%	step jumps; CMJ, hurdle jumps; single-leg jumps	2-4/	1 inter- & intra-complex	1RM Squat: BC: 22.91*, +++ to CTRL RT: 25.90*, +++ to CTRL CTRL: 2.81 CMJ: BC: 1.94 RT: 4.95 CTRL: -0.83 SJ: BC: 9.12* RT: -6.90 CTRL: -3.63 10m sprint: BC: -1.14 RT: -1.68 CTRL: -0.00 Sprint 30-40m: BC: -0.85* RT: -0.85 CTRL: -1.69 40m sprint: BC: -1.10* RT: -1.29 CTRL: -0.93
	6 (m)		22.0 ± 2.5	7/2	Alt. Tr.	RT	half squats; hip flexion	2-5/4-6/ 85-90%	-	-		
	7 (m)		23.0 ± 1.5	7/0	Control	CTRL						
Rodriguez et al. (2017)	10 (m)	semiprofessional adult soccer players, spanish third division	25.4 ± 3.4	6/2	Alt. Tr.	RT	full squats	2-3/4-6/ force system	-	-	3	10m sprint: RT: -2.82* BC: -3.93**, + to CTRL CTRL: -0.56 20m sprint: RT: -1.64**, + to CTRL BC: -2.94***, +++ to CTRL CTRL: -0.66 CMJ: RT: 7.16***, +++ to CTRL BC: 5.29***, + to CTRL
	10 (m)		25.4 ± 3.4	6/2	Complex	BC	full squats	2-3/4-6/ force system	CMJ, COD, sprint	-	3 inter-& intra-complex	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	10 (m)		25.4 ± 3.4	6/0	Control	CTRL	-	-	-	-		CTRL: -0.27 1RM estimated: RT: 16.46***, ++ to CTRL BC: 13.73***, + to CTRL CTRL: -0.97
Smith et al. (2014)*	8 (m/f)	physical education college students; 3-5 trainings/week moderate/vigorous	24.5 ± 4.5	6/3	Complex	CT	squats	3/5/85%	CMJ	3/5/-	0.5-2 inter- & intra-complex	CMJ: CT: 10.61** CT: 9.15** CTRL: 4.33**
	11 (m/f)		24.5 ± 4.5	6/3	Complex	CT	kettlebell swings	3/5/-	CMJ	3/5/-	0.5-2 inter- & intra-complex	
	9 (m/f)		24.5 ± 4.5	6/0	Control	CTRL	-	-	-	-	-	
Stasinaki et al. (2015)*	9 (m)	moderately trained physical education students; no previous systematic resistance training	21.9 ± 2.3	6/3	Complex	CT	leg press; smith box squats	2/6-8/85%	leg press throws; low intensity squat jumps, low intensity drop jumps	2/8/30 %	3 intra-, 5 inter-complex	CMJ: CT: -0.22 Comp: 4.50* CTRL: -1.17 1 RM leg press: CT: 28.48* Comp: 17.76* CTRL: -1.57 1RM Squat: CT: 34.25*, + to Comp Comp: 26.49* CTRL: -1.23
	9 (m)		22.3 ± 2.7	6/3	Alt. P.	Comp	leg press; smith box squats	4/6-8/85%	leg press throws; low intensity squat jumps, low intensity drop jumps	4/8/30 %		
	7 (m)		21.3 ± 1.5	6/0	Control	CTRL	-	-				

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
Talpey et al. (2016)*	9 (m)	active football, basketball, rugby or soccer player	21.4 ± 3.5	9/2	Complex	BS	half squats	3-4/4-6/ 80-90%	jump squats	3-4/4-6	4 inter-& intra-complex	CMJ: BS: 8.12** RBS: 9.55** 20m sprint: BS: -0.91 RBS: -0.31 10 sprint: BS: -1.02 RBS: -2.04 1RM Squat: BS: 24.38** RBS: 23.99**
	11 (m)		20.9 ± 3.6	9/2	Alt. P.	RBS	half squats	3-4/4-6/ 80-90%	jump squats	3-4/4-6		
Torres-Torrelo et al. (2017)*	10 (m)	Spanish third division futsal players; no experience in resistance	24.7 ± 4.7	6/0	Control	CTRL	-	-	-	-	-	10m sprint: CTRL: 0.58 RT: -2.33* BS: -1.16 20m sprint: CTRL: 0.68 RT: -1.34*, + to CTRL BS: -1.00 COD: CTRL: 1.66 RT: -1.87, + to CTRL BS: -1.64 CMJ: CTRL: -0.27 RT: 5.85** BS: 5.31* 1RM estimated: CTRL: -0.97 RT: 16.03***, ++ to CTRL BS: 12.28***, + to CTRL
	12 (m)		23.8 ± 2.4	6/2	Alt. Tr.	RT	full squats	2-3/4-6/ 45-58%	-	-	2-3	
	12 (m)		22.9 ± 4.6	6/2	Complex	BS	full squats	2-3/4-6/ 45-58%	COD	2-5/10sec	2-3	
Tsimachidis et al.	13 (m)	junior basketball players with normal technical	18.0 ± 1.2	10/2	Complex	CT	half squats	5/5-8/80-85%	30m sprint	5/1/-	1.5 inter- & intra-complex	1RM Squat: CT: 29.11*, + to CTRL CTRL: 1.23 SJ: CT: 12.95*, + to CTRL

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	13 (m)	and tactical training experience	18.0 ± 0.7	10/0	Control	CTRL	-	-	-	-		CTRL: 1.72 CMJ: CT: 14.86*, + to CTRL CTRL: 1.32 DJ: CT: 14.12*, + to CTRL CTRL: 2.01
Veliz et al. (2014)*	16 (m)	elite water polo players	20.4 ± 5.1	16/2	Complex	BC	bench press; full squats; military press; pull ups, abs exercise	3-4/6/velocity based	CMJ loaded + CMJ	6/5	n.i.	CMJ: BC: 6.90* CTRL: 2.50 1RM Squat: BC: 14.21*, + to CTRL CTRL: 2.98
	11 (m)		20.4 ± 5.1	16/2	Control	CTRL	-	-	-	-		
Veliz et al. (2015)*	16 (f)	Spanish first division water polo players	26.4 ± 4.3	16/2	Complex	BC	full squats; split squats	7/6/velocity based	CMJ loaded + CMJ	3-6/4-5		CMJ: BC: 8.66 *, + to CTRL CTRL: 2.37 1RM Squat: BC: 20.99*, + to CTRL CTRL: 2.77
	11 (f)		26.4 ± 4.3	16/2	Control	CTRL	-	-	-	-	-	
Villareal et al. (2011)*	14(m/f)	no competitive athletes, but active 2-3 times per week	19.4 ± 1.9	7/3	Complex	BC	full squats; squat power; CMJ loaded	3-4/2-6/velocity-based MP±30%	rebound jumps	4-8/5	n.i.	CMJ: BC: 8.57*** RT: 10.94*** RT: 12.98*** RT: 7.52*** PLYO: 8.39***
	13(m/f)		20.4 ± 2.1	7/3	Alt. Tr.	RT	full squats	3-4/3-6/ 60-85%	-		n.i.	
	13(m/f)		20.2 ± 1.9	7/3	Alt. Tr.	RT	squats	3-4/2-6/MP±30%	-		n.i.	
	13(m/f)		19.6 ± 1.5	7/3	Alt. Tr.	RT	CMJ loaded	3-4/2-5/MP±30%	-		n.i.	

Authors and year	n (gender)	Training Status	Age (years)	Dur. /Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	12(m/f)		20.5 ± 3.7	7/3	Alt. Tr.	PLYO	-	-	rebound jumps	4-8/5	n.i.	
Villareal et al. (2013)*	12 (m)	non-competitive athletes, but active 2-3 times per week	20.4 ± 2.1	7/3	Complex	BC	full squats; squat power; CMJ loaded	3-4/2-6/ velocity-based MP±30%	rebound jumps	4-8/5	n.i.	1RM Squat: BC: 20.23*, + to PLYO RT: 11.11* RT: 17.16* RT: 14.39* PLYO: 6.77* 15m sprint: BC: -0.80 RT: -0.80 RT: -1.40 RT: -0.80 PLYO: -0.70 30m sprint: BC: -0.23 RT: -0.13 RT: -0.33 RT: -0.68 PLYO: -0.91
	12 (m)		20.4 ± 2.1	7/3	Alt. Tr.	RT	full squats	3-4/3-6/ 60-85%	-	-	n.i.	
	12 (m)		20.4 ± 2.1	7/3	Alt. Tr.	RT	squats	3-4/2-6/MP±30%	-	-	n.i.	
	12 (m)		20.4 ± 2.1	7/3	Alt. Tr.	RT	CMJ loaded	3-4/2-5/MP±30%	-	-	n.i.	
	12 (m)		20.4 ± 2.1	7/3	Alt. Tr.	PLYO	-	-	rebound jumps	4-8/5	n.i.	
Wallenta et al. (2016)*	6 (m)	Elite youth soccer players	18.0 ± 1.3	6/2	Complex	CT	squats	3/5/60-70%	3 CMJ + 20m submaximal sprint	3/4	3 intra, 1.5 inter complex	1RM Squat: CT: 7.38*, + BLOCK BLOCK: 7.85 5m sprint: CT: -1.01 BLOCK: -2.00* 10m sprint: CT: -1.74 BLOCK: -1.74* 30m sprint: CT: -1.46 BLOCK: -1.21

Authors and year	n (gender)	Training Status	Age (years)	Dur./Fq.	Training Category	Training Method	Resistance Exercises	Sets/ Reps/ Int.	Plyometric Exercises	Sets/ Reps/ Int.	CT Rest Periods (min)	Change in %
	6 (m)		18.5 ± 1.6	6/2	Alt. P.	BLOCK	squats (3 weeks strength, 3 weeks plyo)	6/5/60-70%	3 CMJ + 20m submaximal sprint	6/4	3/1.5	CMJ: CT: 0.77* BLOCK: 0.98 T-Test: CT: -1.88* BLOCK: -2.50*

f: female; m: male; CT: traditional complex training; BS: block-set complex training; RBS: reverse block-set complex training; Comp: compound training; BC: block complex training; BLOCK: different methods in different weeks; PLYO: plyometric training; RT: resistance training; OLY: Olympic style weight lifting; CTRL: control; CMJ: counter-movement jump; SJ: squat jump; DJ: drop jump; COD: change of direction; * significant intra-group difference (pre-post) (p<0.05); ** significant intra-group difference (pre-post) (p<0.01); *** significant intra-group difference (pre-post) (p<0.001); + significant inter-group difference (p<0.05); ++ significant inter-group difference (p<0.01); +++ significant inter-group difference (p<0.001); n.i.: not indicated; ex.: exercise; Alt. P.: alternative periodization; Alt. Tr.: alternative training method; Dur.: duration; Fq.: frequency; Int.: intensity

4.5 Outcome/Intra-Group Differences

4.5.1 Complex Training

All of the studies under review (41) included at least one group following either a CT, BS, or BC protocol. The following section will describe the intra-group differences (pre-post) in these groups.

1RM:

Eleven of the 17 studies using traditional complex training (CT) tested their subjects for 1RM in leg press or a form of squats. All of them report significant pre-post improvements of their 1RM ranging from 7.38% ($p<0.05$) (Wallenta et al., 2016) to 52.75% ($p<0.05$) (Kobal et al., 2017). Four trials (Brito et al., 2014; Faude et al., 2013; Hammami et al., 2017a, 2017b) report highly significant ($p<0.001$) improvements in 1RM, whereas others (Arazi et al., 2014; Hammami et al., 2018; Kobal et al., 2017; MacDonald et al., 2012; McMaster et al., 2014; Stasinaki et al., 2015; Tsimahidis et al., 2010; Wallenta et al., 2016) report improvements with a lower significance ($p<0.05$).

Four (Kobal et al., 2017; Loturco et al., 2014; Talpey et al., 2016; Torres-Torrelo et al., 2017) of the twelve studies including BS complex training, tested for 1RM and report considerable significant improvements between 12.28% ($p<0.001$) (Torres-Torrelo et al., 2017) and 45.45% ($p<0.05$) (Kobal et al., 2017).

Nine of 14 interventions featuring a BC group tested their subject for 1RM and all of them, except from Juárez et al. (2009), indicate a significant increase of maximal strength between 8.65% ($p<0.01$) (Kotzamanidis et al., 2005) and 28.83% ($p<0.001$) (Franco-Márquez et al., 2015)

Sprint:

Eleven studies using CT tested their subjects on their sprint times over distances from 5 meters to 60 meters (Dodd & Alvar, 2007). All of these, except from Dodd and Alvar (2007); Faude et al. (2013) and Wallenta et al. (2016) report significant improvements in their CT groups. These improvements ranged between -0.90% ($p<0.05$) (McMaster et al., 2014) and -14.97% ($p<0.001$) (García-Pinillos et al., 2014).

Out of the five studies using a BS protocol and testing sprint performance only three report a significant improvement. Lloyd et al. (2016) recorded a significant decrease of sprint times over 10 and 20 meters of -5.26% ($p<0.01$) and -7.14% ($p<0.05$) respectively. Radnor et al. (2017)

and Loturco et al. (2014) tested for sprint acceleration and speed respectively, and reported increases of 2.68% ($p<0.05$) and 14% ($p<0.05$).

Eight interventions tested their BC groups for sprint and six of them report a performance increase over 5 to 40 meters from -0.85% ($p<0.05$) (Ronnestad, Kvamme, Sunde, & Raastad, 2008) to 6.47% ($p<0.001$) (Fathi et al., 2018).

Agility:

Nine interventions featuring CT tested agility by using tests such as back and forward sprint, repeated change of directions drills or standardized agility tests. Except from Dodd and Alvar (2007), and Alves et al. (2010) all other studies (7) show a significant improvement in their athlete’s agility performance ranging from -1.88% ($p<0.05$) in a so-called T-test (Wallenta et al., 2016) to -7.17% ($p<0.001$) in a 4x5m sprint test (Hammami et al., 2017a).

Only one study using BS complex training tested their subjects of agility and does not report a significant amelioration (Torres-Torrelo et al., 2017). None of the BC groups underwent an agility test.

Jump:

The majority of studies (17) featuring a traditional CT group chose jump performance, specifically, jump height or peak power as an outcome variable. 14 out of the 17 studies used exercises such as countermovement jump, squat jump, or drop jump for assessing their subjects’ performance. 10 studies report a significant improvement in various jumping measures. The lowest percentage of change (0.77% ($p<0.05$)) is reported by Wallenta et al. (2016) for CMJ. The highest rate (35.60% ($p<0.05$)) was achieved in McMaster et al. (2014) for CMJ peak power. In general, most studies report improvements of jump performance of more than 9%.

Of the nine studies testing a BS group for jump performance every trial reported significant improvements ranging from 1.77% ($p<0.01$) (Alemdaroglu et al., 2013) up to 39% ($p<0.05$) (Loturco et al., 2014).

12 interventions with BC groups tested jump ability and report significant improvements in this variable. The results are between 5.29% ($p<0.001$) (Rodríguez-Rosell et al., 2017) and 16.58% ($p<0.05$) (Lyttle et al., 1996). Only one trial (Ronnestad et al., 2008) did not result in significantly increased jump performance (CMJ).

Body Fat Percentage:

Overall, only two studies (Fathi et al., 2018; MacDonald et al., 2012) tested their subjects on the development of their body fat percentage and reported the necessary data and percentage changes. Of these, only MacDonald et al. (2012) used traditional CT and report a 5% increase in body fat.

None of the BS groups was assessed for body fat percentage. Fathi et al. (2018), however, tested their BC group for this variable and recorded a decrease in body fat of -7.80% ($p<0.01$).

Sport-Specific Measurements:
None of the studies including a traditional CT group tested their participants for sport-specific measures.

Five interventions including BC or BS protocols indicate a significant performance increase in all of the tested sport specific variables. Lee et al. (2014) report significant time decreases in all on-ice skating drills ranging from -6.60% to -17.20% ($p<0.001$). Fletcher and Hartwell (2004) indicate significant increases of 1.5% and 4.3% in golf club head speed and driving distance, respectively ($p<0.05$). Significant ameliorations are also reported by Labib (2013) for handball jump shot performance (17.62%, $p<0.05$) and Kamal (2016) for composite skillful performance in karate (-10.53%; $p<0.05$). Kramer et al. (1993) also report significant improvements ($p<0.01$) in rowing performance both for “time to row 2500m” (-3.46%) and “distance rowed in 90 seconds” (4.08%).

4.5.2 Alternative Training Methods

22 of the 41 studies included at least one alternative training method (resistance training RT, plyometric training PLYO, Olympic weight lifting OLY) in their investigations. The most prevalent methods are PLYO and RT; only one study features OLY (Arabatzi, Kellis, & Saez-Saez De Villarreal, 2010).

1RM:
The results show that in 13 studies which used RT and PLYO, both training methods lead to significant increases in 1RM leg strength. For the RT groups the range was between 10.03% in Kotzamanidis et al. (2005) and 48.86% in Arazi et al. (2014) ($p<0.05$). Similarly, all the PLYO groups reached significant improvements in maximal strength between 6.77% (de Villarreal et al., 2013) and 44.26% (Arazi et al., 2014) ($p<0.05$). Only one PLYO group in Hammami et al. (2018) could not significantly gain more strength.

Sprint:
16 studies incorporating RT or PLYO tested their participants on sprint performance. Only eleven report a significant improvement over the time of the respective intervention.

Of those interventions using RT, eight indicate significant changes between -0.60% (p<0.05) (McMaster et al., 2014) and 9.82% (p<0.001) (Hammami et al., 2017a) in sprint time. Loturco et al. (2013) tested for speed and also recorded a 16% increase. Five studies of the nine which featured PLYO report significant sprint time improvements ranging from -3.48% (p<0.01) (Fathi et al., 2018) to -15.66% (p<0.05) (Arazi et al., 2014). On the contrary, Fathi et al. (2018) report a deterioration in sprint performance of 4.35% and 2.39% for 5m and 10m sprint, respectively (p<0.05).

Agility:

Three studies (Arazi et al., 2014; Dodd & Alvar, 2007; Hammami et al., 2018) included PLYO and tested the agility of their subjects. Two trials report a significant change of -3.36% (p<0.01) (Hammami et al., 2018) and -7.65% (p<0.05) (Arazi et al., 2014) in their test times. Dodd and Alvar (2007) do not give any indication on the significance of their results.

Four studies tested their RT groups for agility, of which two report significant ameliorations between -2.25% (p<0.05) (Hammami et al., 2017a) and -6.28% (p<0.05) (Arazi et al., 2014). Torres-Torrelo et al. (2017) tested their RT group for agility but their results are not significant.

Jump:

13 studies which featured a RT group tested their subject for jump performance using CMJ, SJ, or DJ. 10 of those trials report significant results ranging from 5.61% (p<0.01) (Kramer et al., 1993) to 46.20% (p<0.05) (McMaster et al., 2014).

Ten studies featured a PLYO or OLY group and except from Radnor et al. (2017), Lloyd et al. (2016) and Dodd and Alvar (2007) every trial reports a significant increase in jump performance. The range is 3.37% (p<0.001) (Fathi et al., 2018) to 20.28% (p<0.05) (Arabatzi, Kellis, & Saez-Saez De Villarreal, 2010). Overall, only Fathi et al. (2018), Lyttle et al. (1996), and de Villarreal et al. (2011) report changes which were below 10 percent.

Body Fat Percentage:

Concerning body fat percentage only two studies report changes in this variable. MacDonald et al. (2012) indicate that both the PLYO and RT group significantly increased body fat percentage by 15.79% (p<0.05). On the contrary, Fathi et al. (2018) report a significant decrease of -7.54% (p<0.01).

Sport-Specific Measurements:

Kramer et al. (1993) tested their RT group on rowing specific measures and report significant (p<0.01) improvements for both time to row 2500m" (-3.04%) and "distance rowed in 90 seconds" (3.56%). No study using a PLYO group tested for sport specific variables.

4.5.3 Alternative Periodization Models

1RM:

Six studies (Arazi et al., 2014; Juárez et al., 2009; Kobal et al., 2017; Stasinaki et al., 2015; Talpey et al., 2016; Wallenta et al., 2016) included alternative periodization models and tested for 1RM; and all of them resulted in significant increase in 1RM ranging from 8.73% ($p<0.01$) (Juárez et al., 2009) to 47.25% ($p<0.05$) (Kobal et al., 2017). Only Wallenta et al. (2016) do not indicate significant change in RM after BLOCK.

Sprint:

Three out of the four studies which tested the sprint performance of their alternative periodization groups report significant improvements of -1.74% ($p<0.05$) in a 10m sprint (Wallenta et al., 2016) up to -15.66% ($p<0.05$) in a 20m sprint (Arazi et al., 2014).

Agility:

Only Arazi et al. (2014) (-2.50%; $p<0.05$) and Wallenta et al. (2016) (-7.88%; $p<0.05$) indicate a significant improvement in agility for their alternative periodization group.

Jump:

Most studies (8) which incorporated alternative periodization models tested for jump performance. Only Wallenta et al. (2016) and Juárez et al. (2009) do not report a significant improvement in CMJ. All others report significant ($p<0.05$; $p<0.01$) ameliorations between 4.50% in CMJ (Stasinaki et al., 2015) and 29.47% in SJ (Alemdaroglu et al., 2013).

Body Fat Percentage / Sport-Specific Measurements:

No alternative periodization group was tested for body fat and sport-specific measures.

4.5.4 Non-Training Controls

1RM:

Overall, 16 studies included a control group which was tested for maximal strength, and none of them reported significant changes.

Sprint:

Out of the 17 studies which tested their control group for sprint performance only one study reported significant improvements. Specifically, García-Pinillos et al. (2014) indicated -12.05% ($p<0.001$) for 5m, -5.61% ($p<0.05$) for 20m, and -3.83% ($p<0.05$) for 30m sprint.

Agility:

Seven studies tested their control groups for agility but did not report any significant changes.

Jump:

22 studies included a jump test for their CTRL and, similar to the sprint variable, only one study reported a significant change of 4.33% ($p<0.01$) in CMJ (Smith et al., 2014).

Body Fat Percentage:

Concerning body fat, only Fathi et al. (2018) measured their subjects' pre and post values in the CTRL but did not report any significant changes.

Sport-Specific Measurements:

Most sport-specific tests in Lee et al. (2014) did not result in significant changes in the CTRL. However, controls did significantly improve their line drill performance by -7.41% ($p<0.001$). In all other studies testing sport-specific measures (Fletcher & Hartwell, 2004; Kamal, 2016; Labib, 2013) no significant increase was reported.

4.6 Outcome/Inter-Group Differences

All studies (41), except from two (Kamal, 2016; Labib, 2013) (T-test), used an ANOVA or a similar statistical method to compare the different training and non-training (CTRL) groups. In 14 cases the ANOVA showed no significant interaction between the different groups. The remaining 25 studies report significant group differences in at least one variable and to at least one group and, consequently, ran a post-hoc test.

4.6.1 Non-Training Controls

None of the control groups in this analysis reached significantly better results than any of the intervention groups. Therefore, it can be stated that training is superior to no training.

4.6.2 Complex Training

1RM:

All studies (41) include at least one form of complex training. Even though all of them report a significant strength improvement from pre to post measurements, nine studies did not report any significant intergroup differences to the other training methods (alt. periodization, alt. training) in the respective intervention concerning maximal strength. Contrarily, 16 studies indicate superiority of complex training over other training methods or controls for strength measures. In particular, 13 studies report significant ($p<0.05$ – $p<0.001$) superiority over non-training controls. Additionally, three studies (de Villarreal et al., 2013; Hammami et al., 2018; Stasinaki et al., 2015) indicate significantly better strength values than in the alternative training groups.

Sprint:

Out of the 23 studies which tested their complex training groups on sprint performance, nine report a significant ($p<0.05$ – $p<0.001$) difference to CTRL or an alternative method. All trials indicate that a complex training form has a more positive effect on sprint performance than no training. Further, two of those studies report higher outcomes through a complex training method (BC and BS respectively) than through an alternative (Kotzamanidis et al., 2005; Radnor et al., 2017).

Agility:

Nine trials tested a complex training group for agility, out of which only two (García-Pinillos et al., 2014; Hammami et al., 2017a) report significantly ($p<0.001$) better results compared to non-training controls. None of the trials indicates that complex training was significantly more effective than an alternative training group or an alternative periodization model.

Jump:

In 33 studies complex training groups were tested for jumping ability. 12 report a significant ($p<0.05$ – $p<0.001$) inter-group difference to CTRL. Four trials indicate that, concerning jump performance, complex training is significantly superior to an alternative training method (Fathi et al., 2018; Hammami et al., 2018; Kotzamanidis et al., 2005; Radnor et al., 2017).

Body Fat Percentage:

Fathi et al. (2018) and MacDonald et al. (2012) assessed their CT groups' body fat percentages of which only Fathi et al. (2018) report significant ($p<0.05$) intergroup differences to the control group. MacDonald et al. (2012) does not indicate superiority of complex training over another training methods in this variable.

Sport-Specific Measurements:

Of the five included studies (Fletcher & Hartwell, 2004; Kamal, 2016; Kramer et al., 1993; Labib, 2013; Lee et al., 2014) which tested a complex training group for sport-specific measures, only Lee et al. (2014) report significant inter-group differences to CTRL. The others do not report significant improvements compared to controls (Fletcher & Hartwell, 2004; Kamal, 2016; Labib, 2013), or to alternative training methods (Kramer et al., 1993).

4.6.3 Alternative Training Methods

1RM:

Among the 14 trials testing alternative training groups for maximal strength, eight (Brito et al., 2014; Hammami et al., 2017a; Kotzamanidis et al., 2005; Loturco et al., 2014; Lyttle et al., 1996; Rodríguez-Rosell et al., 2017; Ronnestad et al., 2008; Torres-Torrelo et al., 2017) report a significant inter-group difference (p<0.05 – p<0.001) between the alternative method and the control group. None report superiority over a complex form or an alternative periodization model.

Sprint:

Six (Brito et al., 2014; Hammami et al., 2017a; Loturco et al., 2014; Radnor et al., 2017; Rodríguez-Rosell et al., 2017; Torres-Torrelo et al., 2017) of the 17 studies which tested their alternative training groups on sprint performance show significantly bigger improvements (p<0.05 -p<0.001) in their PLYO or RT groups compared to their controls. Radnor et al. (2017) further indicate a significantly bigger improvement (p<0.05) of 10m sprint performance of RT compared to PLYO.

Agility:

Two (Hammami et al., 2017a; Torres-Torrelo et al., 2017) among the five interventions testing alternative training forms for agility report significant superiority of RT over non-training controls. The other three do not show such a significant difference (Arazi et al., 2014; Dodd & Alvar, 2007; Hammami et al., 2018).

Jump:

21 interventions tested alternative training groups for jump ability and six of them (Arabatzi, Kellis, & Saez-Saez De Villarreal, 2010; Hammami et al., 2017a; Loturco et al., 2014; Lyttle et al., 1996; Radnor et al., 2017; Rodríguez-Rosell et al., 2017) report significantly better outcomes (p<0.05 – p<0.001) compared to the respective non-training control group.

Body Fat Percentage:

Overall, only Fathi et al. (2018) report a significant (p<0.01) inter-group difference between an alternative method (PLYO) and the CTRL. Others (MacDonald et al., 2012), who also assessed body fat percentage in alternative training groups do not indicate a significant difference to any other method.

Sport-Specific Measurements:

Only Kramer et al. (1993) tested an alternative group on sport-specific measures, but do not report superiority over another training method.

4.6.4 Alternative Periodization Models

Among the five studies (Arazi et al., 2014; Juárez et al., 2009; Mihalik et al., 2008; Stasinaki et al., 2015; Wallenta et al., 2016) including alternative periodization models only Arazi et al.

(2014) report a significant ($p<0.05$) inter-group difference between compound training and no training. Apart from this, no significant inter-group difference is indicated.

5 Discussion

5.1 Training Protocols

In this section the different training methods will be compared according to the overall changes in the different performance measures. It has to be highlighted that the comparisons are only based on the mean values of the collected data. All of the data show a very high variance and, consequently, have to be treated with caution. More valid conclusions would require more differentialized statistic or meta-analytic operations, which would be too extensive for this analysis.

5.1.1 CT vs. BS, BC

As elaborated in chapter 2.4 the underlying mechanism of complex training is the post-activation potentiation (Sale, 2002). It is stated that muscle performance, and especially muscular power, benefits from the "higher potentiated state after a conditioning activity" (Chu, 1983). Consequently, it is of interest if this potentiated state is exploited more if the sequence of exercises is aligned as described by (Ebben, 2002) in an alternating set-by-set fashion, or as in BS or BC. If a plyometric exercise repeatedly follows a CA while the muscle is still in this potentiated state, this should result in higher use of the PAP effect. This repeated attempt to induce PAP may have a positive effect on the improvement of performance measures in general (Wallenta et al., 2016, p. 36). In the present data (Figure 7) the mean values of jump performance change are higher in the traditional complex training groups than in the block complex and block set complex groups (BC 8.88% ± 3.75; BS 10.95% ± 9.76; CT 11.35%; ± 8.77). However, clear conclusion may not be drawn from these numbers as the variance is very high and the differences are very small.

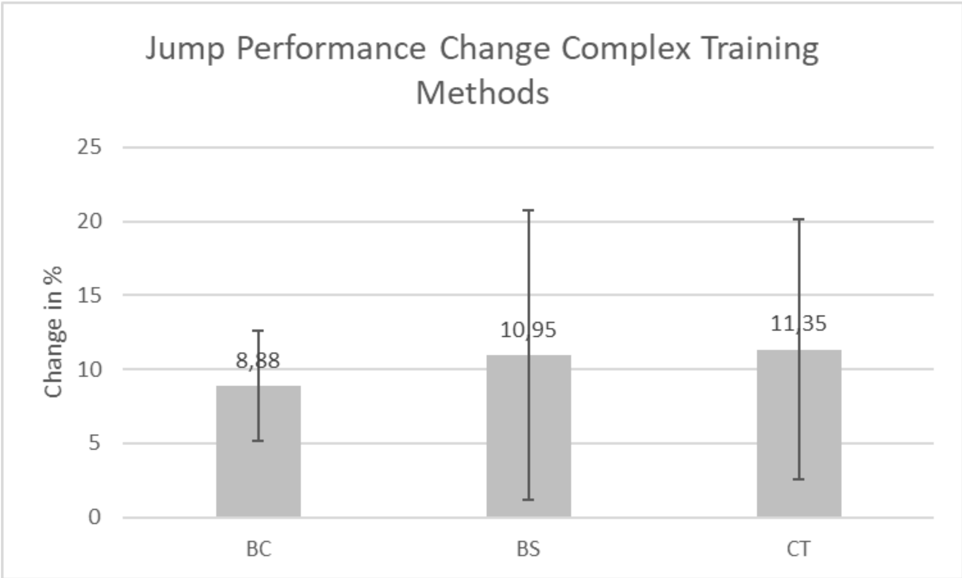

Figure 7: Jump Performance Change Complex Training Methods

Accordingly, those studies which did compare two complex training forms and tested them for jump performance (Alemdaroglu et al., 2013; Kobal et al., 2017) could not find any significant differences between the training groups concerning jump performance. According to Alemdaroglu et al. (2013, p. 216) combination training has positive effects on jump performance, but "[…] independently of the order of the exercises[…]". Similarly, Kobal et al. (2017) report increases in jump performance in all of their groups, but suggest that, especially at high training levels, in order to improve jump ability "[…] performing higher volumes of PT is more important than training at these theoretical 'potentiated states'".

Concerning strength performance, the overall trend of the present data is similar. Figure 8 shows that CT groups had higher improvement percentages and a higher mean value compared to the other two complex forms (BC 17.11% ± 6.58; BS 27.03% ± 13.73; CT 32.54% ± 14.85). However, the variance is again very high, so that conclusion may not be drawn. Further, none of the 41 included studies both compare two forms of complex training and test for strength.

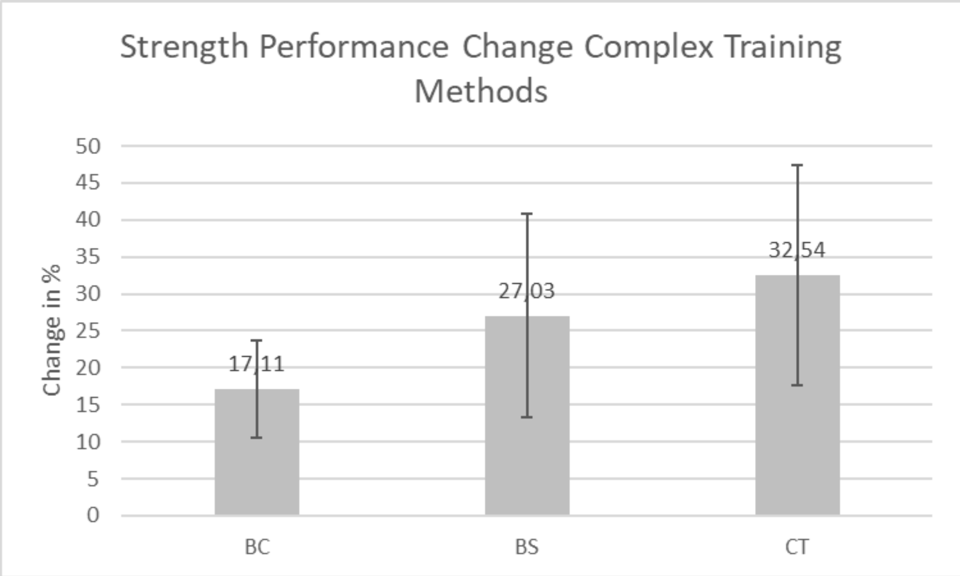

Figure 8: Strength Performance Change Complex Training Methods

Sprint performance values draw a similar picture (Figure 9). Although the CT groups show higher mean performance ameliorations than the BC and BS groups of the studies under review, the variance is too high to formulate solid claims.

Figure 9: Sprint Performance Change Complex Training Methods

Based on the present data, comparisons between BC, BS and CT concerning agility, would not be significant as only one intervention featured BC and tested for agility (Torres-Torrelo et al., 2017). The other nine studies including a complex training group and testing agility included only a CT group (see chapter 4.5.1.)

For body fat percentage, MacDonald et al. (2012) report an increase of 5% (relative) for their CT group consisting of recreationally trained male college students, whereas Fathi et al. (2018)

report a change of -7.80% for their BC group consisting of Tunisian professional volleyball players. However, MacDonald et al. (2012) highlight that the slight and non-significant increase in body fat is a response to the heightened caloric demand during the training period and is not directly caused by this specific training method in particular.

Operationalizing data for sport-specific performance in this analysis is difficult as only five interventions (Fletcher & Hartwell, 2004; Kamal, 2016; Kramer et al., 1993; Labib, 2013; Lee et al., 2014) tested for these variables and the kinds of tests differed considerably. Further, none of these studies included a traditional CT group. As seen in chapter 4.5.1, all the complex training groups (both BS and BC) improved their performance significantly, but only one (Lee et al., 2014) reports a significant group difference to CTRL.

5.1.2 Complex Training Methods vs. Other Training Methods

As it would be too extensive to compare every single method and variable with each other, the following section will pool the training methods, and compare and discuss the outcomes for the different variables.

Jump:

As shown in Figure 10, the mean value of jump performance is highest for alternative periodization methods (13.00% ± 9.76), lower for alternative training methods (10.66% ± 9.75) and again slightly lower for complex training methods (10.43% ± 7.65). Further, the results are considerably lower for CTRL (0.15% ± 2.73) suggesting that all training methods are superior to no training. However, statements based on these values would not be completely reliable as variance is too high.

The overall trend, though, is in line with the conclusions in Lesinski et al. (2014) who report that, generally, complex training forms do not seem to be significantly superior to alternative training methods, but both lead to significant positive pre-post changes. Others, however, report significantly better results in jump performance for complex training than for alternative training methods (Fathi et al., 2018; Hammami et al., 2018; Kotzamanidis et al., 2005; Radnor et al., 2017). These improvements could be traced back to an improved storing capacity of elastic energy during the SSC caused by complex training (Fathi et al., 2018; Hammami et al., 2018). Similarly, Radnor et al. (2017) put forward that superior improvements of jump performance between complex training and, especially, resistance training may occur due to the mode of training and exercise execution. Due to the lack of rapid exercise execution and, thus, SSC in strength training, training methods, like CT and PLYO, which tackle factors such as rapid firing, “reactive strength” and “high rates of force development” may lead to better jumping results.

Figure 10: Jump Performance Change Overall

Strength:

According to the data in Figure 11 the mean increase in strength performance is highest for complex training forms. Complex training groups in the included studies show a mean value for strength improvement of 26.35% (± 13.9), followed by alternative periodization methods with 24.52% (± 14.94) and alternative training methods with 21.58% (± 12.53). Controls reached a mean value of 2.02% (± 2.49), meaning that no training is in general inferior to any training method concerning strength performance. Again, definite conclusions are hindered by the very high values for standard deviation.

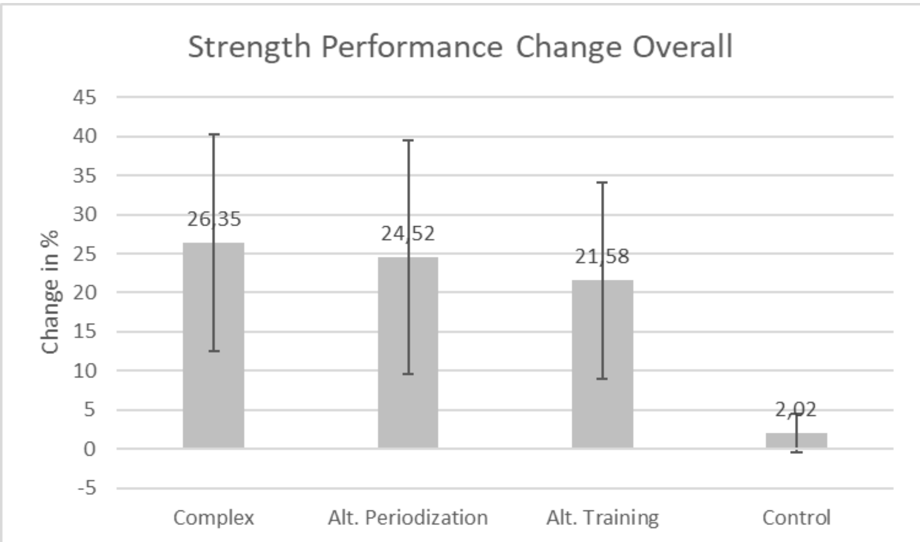

Figure 11: Strength Performance Change Overall

Hammami et al. (2018) and de Villarreal et al. (2013) support the slight trend in the present data as they indicate a significantly higher performance increase in 1RM strength for CT compared to PLYO; however, not to RT. de Villarreal et al. (2013) indicate that the increase in in strength was significantly higher ($p<0.05$) in the CT group (20.23%) than in the plyometrics group (6.77%). However, no difference was observed between CT and all of the three RT groups in this study. Similarly, Hammami et al. (2018) report significantly better results for CT compared to PLYO, but again not to RT. The authors mention that while the RT group increased their 1RM and their muscle cross-section, the CT did not, but both improved their 1RM performance significantly. Consequently, it may be argued that complex training may result in higher strength performance due to an improved neurological muscle activity (Gabriel, Kamen, & Frost, 2006, p. 145; Hammami et al., 2018, p. 13).

Additionally, Stasinaki et al. (2015) and Wallenta et al. (2016) report significant inter-group differences between CT and an alternative periodization model (BLOCK, Comp) in favor of CT. According to Wallenta et al. (2016, p. 36) these improvements could result out of the repeated induction of the PAP effect in CT, which is non-apparent in an alternative periodization method. Furthermore, Stasinaki et al. (2015, p. 14) indicate that although both CT and Comp increased their strength performance, CT also increased muscle cross-section, which may be evidence for the higher potential of CT to improve maximal strength. Consequently, CT showed a significantly greater improvement ($p<0.05$) in 1RM strength than Comp in this study.

In contrast, of the four interventions which compared both a resistance training protocol and a plyometrics protocol to a complex training method only de Villarreal et al. (2013) report significantly better results in CT than in PLYO. The others either report no inter-group difference (Arazi et al., 2014; MacDonald et al., 2012) or only to CTRL (Brito et al., 2014) which could be related, again, to neuromuscular adaptations in either group (Brito et al., 2014, p. 126).

Sprint:

As mentioned in chapter 4.4 and 4.5 the sprint/agility data are presented as negative values indicating shorter sprint times. Overall, it can be observed (Figure 12) that the highest mean values are again achieved by complex training methods (complex: -4.51% ± 4.29; alternative periodization: -3.66% ± 4.44; alternative training: -2.65% ± 4.08; CTRL: -0.68% ± 2.97). Nevertheless, the values for sprint time include so many variables in this pooled visualization (5m - 60m) that definite conclusions cannot be drawn from this analysis. Furthermore, the variance is again very high. However, it can be argued that all training forms seem to be superior to no training.

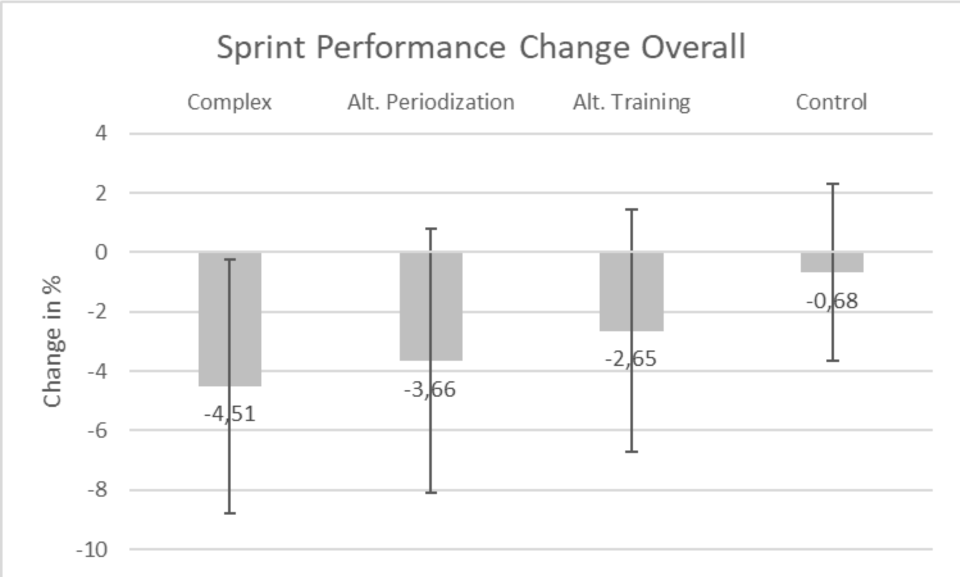

Figure 12: Sprint Performance Change Overall

Only two interventions (Kotzamanidis et al., 2005; Radnor et al., 2017) report a significant inter-group difference for sprint ($p<0.01$, $p<0.05$ respectively) between an alternative training method and a complex training method in favor of the latter. Kotzamanidis et al. (2005) indicates that BC was more effective than RT for 30m sprint and tracing it back to better neuronal adaptation in the BC group, but also to the circumstance that possible strength improvement in RT could not be transferred to sprint performance (Kotzamanidis et al., 2005, p. 373). This may be due to the muscles' limited capacity to cope with the recently altered muscular structure (Delecluse, 1997, p. 152).

Agility:

Concerning agility, alternative periodization methods show the highest mean values. However, it is important to note that only two alternative periodization trials were tested for agility. Therefore, these numbers may be attributed with lower significance. The results of those training methods, of which many samples are apparent among the included studies, show relatively equal values. All of the means show a very high variance. Overall, Figure 13 illustrates that the differences in means between the training categories are rather small, but considerable compared to CTRL (complex: -4.07% ± 2.12; alternative periodization: -5.19% ± 3.80; alternative training: -3.55% ± 2.36; CTRL: -0.03% ± 0.99). In general, it can be noted that agility improvements in relative numbers where considerably lower than those for strength or jump performance.

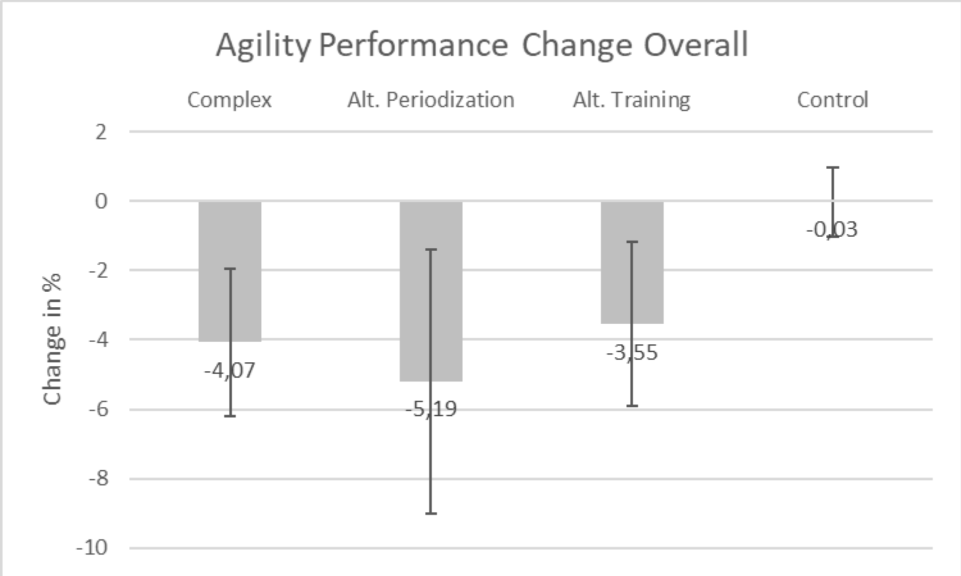

Figure 13: Agility Performance Change Overall

Interestingly, higher improvements (over 4%) in agility performance can be observed in those studies which included sprint or some sort of running or agility drills in their CT groups. Hammami et al. (2018), Hammami et al. (2017a) and Hammami et al. (2017b) included 15m sprints in their complex training and report significant improvements ($p<0.01$ and $p<0.001$) over 4% in several agility tests, such as ROCD (repeated change of direction) test, 4x5m sprint and 180° turn sprint. Arazi et al. (2014) and Faude et al. (2013) included zigzag drills in their CT protocols and also report significant improvements in agility ($p<0.05$, $p<0.01$). In addition to the improved neuromuscular capacities of the muscles after a CT training intervention (Hammami et al., 2017b, p. 1430) improvement could root in "test familiarization" (Faude et al., 2013, p. 1466) as the subjects may got used to running and changes of directions in training. Furthermore, the increased agility performance may also be altered due to the improved muscle qualities, such as cross-section or concentric strength. (Sheppard & Young, 2006, p. 222f.)

Body Fat Percentage:

Only two trials (Fathi et al., 2018; MacDonald et al., 2012) report their subjects' change in body fat percentage. Fathi et al. (2018) report significant decreases in body fat for both CT (-7.80%) and PLYO (-7.54%) and significantly better results compared to controls ($p<0.01$). In contrast, all training groups in MacDonald et al. (2012) increased their body fat percentage over the course of the intervention. Especially, RT and PLYO significantly ($p<0.05$) increased by 15.79%, whereas CT increased by (non-significant) 5%. The authors trace back this increase to the non-supervised diet during the intervention and the heightened caloric intake due to the training sessions, and not to a specific training method itself (MacDonald et al., 2012).

According to the present data, no conclusions can be drawn concerning a possible superiority of any of the training methods concerning body fat percentage change. However, it would be interesting for future interventions to track changes in body composition. To do so, it would be crucial to track or supervise the subjects' diet throughout the intervention.

Sport-Specific Performance:

Four of the five studies testing for sport-specific measures feature a CTRL group and report better results in the respective complex training group (Fletcher & Hartwell, 2004; Kamal, 2016; Labib, 2013; Lee et al., 2014) which means that complex training can have a positive effect on sport-specific measures. However only in Lee et al. (2014) the differences to CTRL are significant. Unfortunately, only one of those five studies compared a complex form with another training method (Kramer et al., 1993). Further research should be aiming at investigating a possible superiority or inferiority of complex forms compared to other training methods. Interestingly, Kramer et al. (1993) who compare RT to BC report similar degrees of performance change in their subjects' time to row 2500m and distance rowed in 90s. This circumstance is likely to root in the fact that both groups included rowing in their training programs and, therefore, executed the movement, which was tested in the end, over the entire intervention period. The additional stimulus which was given through the inclusion of plyometric exercises might have been too small to result in additional performance benefits.

5.2 Rest Intervals

One of the most inconsistent, or even often neglected factor in the included studies is the indication of rest periods. Taking into account that, according to Seitz and Haff (2016) the PAP-effect "[…] is larger after shorter recovery intervals and single-set and RM CAs among stronger individuals, while longer recovery intervals, multiple-set CAs, and submaximal CAs are more effective at inducing PAP in weaker individuals", training status and rest intervals seem to be essential when it comes to training protocol design. Nevertheless, only 24 of 41 studies indicated the inter- and/or intra-complex rest periods of their complex training groups.

Eleven of those studies used an intra-complex rest of less than three minutes (Alemdaroglu et al., 2013; Arazi et al., 2014; Dodd & Alvar, 2007; Faude et al., 2013; Kamal, 2016; Labib, 2013; Lloyd et al., 2016; Mihalik et al., 2008; Ronnestad et al., 2008; Smith et al., 2014; Tsimahidis et al., 2010). The claim may be right that the induced PAP is higher after a certain rest interval and for certain training levels, however, this may not be fully supported by the present data. All the complex training groups with short intra-group in the studies mentioned above achieved significant performance gains. The short rest periods here, however, do not seem to correlate with the training status as there are groups which feature untrained or inexperienced subjects (Arazi et al., 2014; Kamal, 2016; Labib, 2013; Lloyd et al., 2016) which did increase their performance significantly across various measures. On the other hand, there are also inexperienced subjects who significantly improved their performance (Arabatzi, Kellis, & Saez-Saez De Villarreal, 2010; Juárez et al., 2009; Stasinaki et al., 2015) after a complex training program with longer rest periods. This lack of support, however, is very likely to be caused by the considerable diversity of study designs, subjects, and performance measures in the studies under review.

Furthermore, Freitas et al. (2017, p. 14) highlight that the studies analyzed in Seitz and Haff (2016) were all acute interventions and not long-term studies. Therefore, it may be invalid to directly transfer their outcomes to long-term studies, because in a multi-set and multi-exercise training protocol intra-complex rest periods of up to eight minutes would more likely result in a decrease of PAP or some sort of cool down effect. What is more, such a long rest between every complex pair would be highly impractical. Further research is necessary to investigate this issue. For instance, a long-term intervention, which compares equal complex training protocols with different rest interval could deliver new insights in this matter.

5.3 Training Status

As slightly tackled in the previous section, training status appears to be another key factor influencing PAP and complex training. Conflicting claims can be found in literature tackling this issue. While many (Aagaard & Andersen, 1998; Cormie et al., 2011b; Haff & Nimphius, 2012; Seitz & Haff, 2016) indicate that better trained athletes profit more from complex training, Juárez et al. (2009, p. 239f.), for example, state that “[…] complex training seems to be an interesting option for developing strength in untrained subjects”. However, it has to be noted that in this study no significant superiority over other training methods was reported.

The data in this analysis, may not support neither side of this controversy. For instance, in jump performance, the most significant improvements ($p<0.001$, $p<0.01$) were measured in studies featuring diverse training levels (Alemdaroglu et al., 2013; Alves et al., 2010; García-Pinillos et al., 2014; Hammami et al., 2018; Hammami et al., 2017a; Smith et al., 2014). The subjects in Alves et al. (2010), for instance, performed soccer on a professional level, but had no experience in strength training. On the contrary, two of those trials included subjects on an amateur level, but had undergone some sort of systematic strength training (Hammami et al., 2017a) or had participated in at least 3-5 systematic training sessions per week on a regular basis (Smith et al., 2014).

The outcomes for strength offer even less support as every single complex training group significantly improved strength performance considerably regardless of the training status. Concerning sprint, agility and sport-specific measures the outcomes are either so diverse or show a too small sample size, that definite statement may not be made. Further, no study compared subjects of different experience levels following the same complex training protocol. A study with this design might shed more light on this matter and might be an attractive option for future research.

5.4 Load Prescription

Another crucial factor for inducing PAP appears to be the load of the respective conditioning activity. In general, it is stated that high intensities should be used for inducing a high PAP effect (Ebben & Watts, 1998, p. 23). In contrast, Wilson et al. (2013) and Freitas et al. (2017) claim that lower loads below 80%1RM are more effective.

Several studies in this analysis used high loads over 80%1RM for their conditioning activities and indicate performance gains and, therefore, positive effects of complex training with high loads on maximal strength, jump and partly sprint. McMaster et al. (2014) used the highest loads between 85% and 99% and report significant increases ($p<0.05$) in 1RM squat, 10m, 20m, 30m sprint, and CMJ. Alves et al. (2010) used loads between 80% and 100% and, also, indicate significant gains in sprint and SJ performance. Furthermore, Kotzamanidis et al. (2005) and Brito et al. (2014) used loads between 80% and 90%/95% and indicate performance improvement in 1RM, SJ, DJ, CMJ and 30m sprint, and 1RM and 20m sprint respectively.

Talpey et al. (2016) and Dodd and Alvar (2007), also, used high load (80% - 90%) CAs, but, in contrast to the others, do not report significant improvement in sprint performance. Improvements in strength and jump measures were also apparent, though.

In contrast, Torres-Torrelo et al. (2017) for example, used the lowest loads (45-58%) for the conditioning activity (full squat) in their complex training protocol (BS). The authors tested third division futsal players with no resistance training experience for 10m and 20m sprint, COD, CMJ, and 1RM squat. The complex training protocol resulted in a non-significant change in the sprint and agility measures, but in a significant improvement in CMJ ($p<0.05$) and 1RM squat ($p<0.001$). Only, the value for 1RM was significantly higher than in the control group.

Franco-Márquez et al. (2015) tested young male soccer players without any strength training experience and used loads between 45% and 58% for the CA of their complex training program (BC). The training protocol resulted in a non-significant change for 10m sprint, but the other tested variables (20m sprint, CMJ, 1RM squat) improved significantly ($p<0.05$, $p<0.001$) and were significantly higher than in the control group ($p<0.001$).

Arazi et al. (2014) tested untrained women and used rather low intensities (60%). The authors report a significant ($p<0.05$) improvement in all the tested parameters (1RM, CMJ, 20m sprint, agility).

Interestingly, although using low loads, all of those three studies report a significant improvement in strength and jump measures but, also, differ in sprint or agility. According to the present data it is controversial to draw conclusions on whether load prescriptions have a certain impact on performance measures. However, it appears that both high- and lower-load CAs may result in significant performance improvements, especially for strength and jump measures. Again, the great diversity of the analyzed studies represents a limitation for such a claim.

5.5 Exercise Selection

Several sources thematize the selection of the most efficient exercises or contraction form for inducing a high PAP effect in complex training (Desmedt & Godaux, 1977; Ebben, 2002; Ebben & Watts, 1998; Seitz & Haff, 2016). While some argue that isometric contractions may be preferred (Sale, 2002), others highlight the superiority of plyometric activities or high-load concentric contractions as conditioning activities (Seitz & Haff, 2016). In this analysis only two studies included a partly plyometric exercise (CMJ loaded) as a CA in their complex training protocol (de Villarreal et al., 2011; de Villarreal et al., 2013). As both studies also used regular full squats as CA no conclusions on the effect of a plyometric CA can be drawn.

Surprisingly, very few sources address the choice of the plyometric exercises in the complex pair. Ebben (2002) suggests "biomechanically similar" exercises, such as jumps or hops after lower body exercises, such as squats, or bench press throws after upper body exercises, like bench press. Some also include sprints (Hammami et al., 2017a; Wallenta et al., 2016) or skipping (Alves et al., 2010) into their complex training workout, but clear suggestions are comparatively rare. Therefore, the variety of exercise choices is very rich.

Interestingly, all the studies with high load CAs mentioned in section 5.4, improved strength and jump performance, but only those which also included sprint exercises into their complex training protocol (Alves et al., 2010; Brito et al., 2014; Kotzamanidis et al., 2005; McMaster et al., 2014) report significant sprint time improvements. Those who did not include sprint (Dodd & Alvar, 2007; Talpey et al., 2016), do not report significant sprint ameliorations. Similarly, as mentioned in section 5.1.2 (agility), the highest improvements in agility are reported in those studies which also feature agility or running exercises in their complex training program. This could mean that improvements of this kind are not solely linked to alterations due to complex training, but also due to a certain familiarization effect, as the exercises used in training and those in testing are similar (Faude et al., 2013, p. 1466). More research would be necessary to investigate a possible influence.

5.6 Model Study

Taking all the previously discussed factors into consideration, the following section will introduce a model study, investigating whether the ability to induce PAP can be trained over a certain period of time. Similar to the study of Tsimachidis et al. (2013), repeated measurements of PAP within a complex pair shall help to draw conclusions on whether the PAP effect itself increases over time if it is repeatedly evoked during every session of a long-term intervention.

5.6.1 Subject Characteristics

The participants should be recruited among young adults who are participating in the same professional or semi-professional sports club to ensure that they show a relatively equal training level and follow the same generalized workout program. Further, they should be required to have at least 6 months of experience in either traditional resistance training or any comparable sort of strength conditioning. In order, for the subjects, to be eligible to participate, the study should prerequisite a training status of at least “intermediate” state, which means, according to Baechle and Earle (2008, p. 384), that they are “currently training”, show at least the above mentioned “training age” with a training frequency of 2 to 3 times per week, and are at least on a “basic level” concerning “technique, experience and skill”. Furthermore, the subjects’ 1RM for the training exercise squat must at least be 1.5 times the participants’ body weight. These subjects should then be randomly assigned to one out of three groups (complex training group CT, block complex training group BC, control group CTRL). Participants suffering or having suffered from any severe injury within the last 12 months should not be permitted participation. Furthermore, subjects suffering any severe/chronic disease should be prohibited to partake in the study. All participants should be asked to fill in a statement declaring that they can drop out of the study without having to mention specific reasons.

In order to ensure an acceptable technique in all the training exercises, the subject should at least undergo a 2-weeks preparation phase in which they get accustomed to the correct exercise techniques and to eliminate possible bias due to a differing amount of expertise (Arabatzi, Kellis, & Saez-Saez De Villarreal, 2010; Franco-Márquez et al., 2015; Hammami et al., 2017a; Kobal et al., 2017; Torres-Torrelo et al., 2017).

5.6.2 Training Protocols

The subjects should be exercising at least twice a week for a period of eight consecutive weeks in a strength and conditioning laboratory or a similar facility in which they are supervised by at least one experienced, qualified trainer/researcher. The intervention groups (CT, BC) should follow a standardized warm-up protocol prior to every training and testing session. This protocol includes 10 minutes on 50 (+- 10) rpm on the bicycle ergometer and eight repetitions in every exercise with 50% of their 1RM.

The subjects perform four exercises / two complex pairs in two different body segments respectively (lower and upper body). The exercises for the upper body include bench press and weighted push-ups. The lower body exercises include back squats and leg press. Furthermore, to ensure complete and balanced workouts in this 8-week period, the protocols include three sets of pull-ups as a final part of each training session.

The loads for the different strength exercises in their progression over the timespan of the study will be calculated from the 1RM, as it "appears to be more accurate to assign loads based on a percentage of a test-established 1RM than it is to estimate a 1RM from a submaximal load" (Baechle & Earle, 2008, p. 395). Between the training days a rest period of at least 42 hours is recommended (MacDonald et al., 2012, p. 425). The loads for the first four-week period will be calculated from the initial 1RM test and adapted after the second 1RM test in week five.

5.6.2.1 Complex Training Protocol

In Table 7 the complex training protocol is visualized. The rest periods between the complex pairs are three minutes. As done and suggested in previous studies, such as MacDonald et al. (2012, p. 27), the interval within the complex pairs will only be 30 seconds. According to Seitz et al. (2014, p. 714), a shorter rest period is more beneficial in this case, as the training level of the subjects would be very high. After every set of the high-load exercise and the 30 seconds rest period, the respective plyometric exercise will be executed. According to Ebben and Watts (1998, p. 23) the number of repetitions should be between 5 and 15. The complex pairs are: Back squats and squat jumps; leg press and counter movement jumps; weighted push ups and plyometric push ups; bench press and bench press throws on the smith machine.

Table 7: Complex Training Protocol

		Training Day 1			Training Day 2		
Week		**%1RM**	**Repetitions**	**Plyometrics**	**%1RM**	**Repetitions**	**Plyometrics**
T1		Pre-test					
1	PAP-test	80	3x5	3x8	80	3x5	3x8
2		80	3x5	3x8	80	3x5	3x8
3		80	3x5	3x8	80	3x5	3x8
4		80	3x5	3x8	80	3x5	3x8
T2		Intermediate test					
5	PAP-test	80	3x5	3x8	80	3x5	3x8
6		80	3x5	3x8	80	3x5	3x8
7		80	3x5	3x8	80	3x5	3x8
8	PAP-test	80	3x5	3x8	80	3x5	3x8
T3		Post-test + PAP-test					

5.6.2.2 Block Complex Training Protocol

The second group would perform the same exercises as the complex training group, but in a different order. Similar to other studies (Arabatzi, Kellis, & De Villarreal, 2010; Ronnestad et al., 2008) the BC-group will first execute all the heavy load exercises in one block (back squats, bench press, leg press, weighted push-ups, pull ups) followed by the plyometric exercises in a second block (squat jumps, bench press throws, countermovement jumps, plyometric push-ups).

Table 8: Block Complex Training Program

		Training Day 1			Training Day 2		
Week		**%1RM**	**Repetitions**	**Plyometrics**	**%1RM**	**Repetitions**	**Plyometrics**
T1				Pre-test			
1	PAP-test	80	3x5	3x8	80	3x5	3x8
2		80	3x5	3x8	80	3x5	3x8
3		80	3x5	3x8	80	3x5	3x8
4		80	3x5	3x8	80	3x5	3x8
T2				Intermediate test			
5	PAP-test	80	3x5	3x8	80	3x5	3x8
6		80	3x5	3x8	80	3x5	3x8
7		80	3x5	3x8	80	3x5	3x8
8	PAP-test	80	3x5	3x8	80	3x5	3x8
T3				Post-test			

5.6.2.3 Control Group

The control group should be a non-training group. The subjects in this group should be advised to maintain their regular in-club training routine but refrain from any other form of strength or plyometric training.

5.6.3 Testing Protocols

In order to investigate the defined phenomena, there should be two different test protocols in the course of this intervention. The first one includes the pre-, intermediate and post-tests which measure the subjects' current status and overall development in the variables 1RM, maximum voluntary power output, and jump height. The second protocol should be implemented in the testing sessions, but within the respective complex pairs to examine the PAP-Effect and its continuous development over time (Tsimachidis et al., 2013; Tsimahidis et al., 2010).

5.6.3.1 Pre-, Intermediate and Post-Tests

As a variable to draw conclusions on the PAP-effect the maximal voluntary power output in the light explosive movements will be measured. In order to evaluate the subjects' current state in the beginning, the middle, and their overall development in the end of the intervention, there should be a pre-test in the first week, an intermediate test in the fifth week and a post-test after the last week of the intervention (Lesinski et al., 2014). The pre-test should take place in the week before the intervention starts; the intermediate test in the fifth week as a replacement for the first training session of this said week; the post-test should be held in the week after and at least 48 hours after the last training session. All of these tests should not be run closer than 48 hours before or after the actual training session to ensure that they do neither influence each other.

Prior to the pre-, intermediate and post-test, a general warm-up should be executed. This protocol includes 10 minutes on 50 (+- 10) rpm on the bicycle ergometer and eight repetitions in every exercise with a low load. This load will be determined according to the subjects prior training experience as long as the 1RM is not yet determined. These warm-up sets allow the subjects to get used to the exercises tested and give the conductors the possibility to make form corrections.

5.6.3.1.1 Maximum Power Output

In the mentioned testing sessions, first, the maximum power output when performing the light explosive movement (squat jumps, countermovement jumps, plyometric push-ups, bench press throws on smith machine) will be measured. In these tests the subjects perform three countermovement jumps, three squat jumps, three plyometric push-ups on a force plate, and three bench press throws in the smith machine using a linear position transducer. The best performance in each exercise is used as basis for further statistical analysis. Between the repetitions and the different exercises should be at least a two-minute rest interval, respectively. The tests for lower and upper body will be alternated, to ensure an efficient testing procedure for the high number of subjects, and an optimal rest between exercises targeting the same muscle groups.

5.6.3.1.2 1-Repetition Maximum

As a second part of the testing session procedure, a measurement of the one repetition maximum (1RM) for both the upper body and the lower body muscle segments of the exercises under observation (bench press, weighted push up, back squat, leg press) is executed. These tests will be run on a separate day at least 24 hours apart from the plyometric / maximum power output tests to eliminate possible unwanted effects due to fatigue. The 1RM should be tested with respect to the NSCA guidelines (Baechle & Earle, 2008, p. 396) through the "1RM Testing Protocol". This protocol includes the following steps:

1. Instruct the athlete to warm up with a light resistance that easily allows 5 to 10 repetitions.
2. Provide a 1-minute rest period.
3. Estimate a warm-up load that will allow the athlete to complete three to five repetitions by adding
   a. 10 to 20 pounds (4-9 kg) or 5% to 10% for upper body exercise or
   b. 30 to 40 pounds (14-18 kg) or 10% to 20% for lower body exercise.
4. Provide a 2-minute rest period.
5. Estimate a conservative, near maximal load that will allow the athlete to complete two to three repetitions by adding
   a. 10 to 20 pounds (4-9 kg) or 5% to 10% for upper body exercise or
   b. 30 to 40 pounds (14-18 kg) or 10% to 20% for lower body exercise.
6. Provide a 2-minute rest period.
7. Make a load increase:
   a. 10 to 20 pounds (4-9 kg) or 5% to 10% for upper body exercise or
   b. 30 to 40 pounds (14-18 kg) or 10% to 20% for lower body exercise.
8. Instruct the athlete to attempt a 1RM.
9. If the athlete was successful, provide a 2- to 4- minute rest period and go back to step 7.

   If the athlete failed, provide a 2- to 4-minute rest period, then decrease the load by subtracting

   5 to 10 pounds (2-4 kg) or 2.5% to 5% for upper body exercise or
   15 to 20 pounds (7-9 kg) or 5% to 10% for lower body exercise.

   AND then go back to step 8.
   Continue increasing or decreasing the load until the athlete can complete one repetition with proper exercise technique. Ideally, the athlete's 1RM will be measured within three to five testing sets. (Earle 2006 in: Baechle & Earle 2008, p. 396)

If a safe execution is not possible, the 1RM will be estimated according to the model by the NSCA (Baechle & Earle, 2008, p. 398).

The initial 1RM test results will be used to determine the loads for the respective exercises for the first meso-cycle (weeks 1 to 4). The 1RM test results of the intermediate test session will then be used to adjust the loads of the heavy load exercises in the second meso-cycle (weeks 5 to 8).

5.6.3.2 PAP-Effect Testing

In order to monitor the development of the PAP-effect over the intervention, it is necessary to run multiple tests during this period (Lesinski et al., 2014). Therefore, in addition to the general parameters (see 5.6.3.1.1 and 5.6.3.1.2.), the participants are tested for PAP in the first training session following the initial pre-test and the intermediate test, and in the session preceding the post-test. To test the PAP-effect, the participants perform one set of the heavy load exercise and after a 30-second rest interval the maximal power output in the respective plyometric exercise will be tested with the matched testing method/device (see 5.6.3.1.1.). Such a measurement will be executed during every first complex pair of one complex (e.g.: first set of squats -> three squat jumps on force plate -> first regular set of squat jumps -> remaining complex pairs).

6 Conclusion

The overall purpose of this thesis was to systematically review all the relevant literature and investigate the effects of complex training on variables, such as maximal strength, jump performance, sprint performance, agility, body fat percentage and various sport-specific measures. Furthermore, it should analyze, how factors, such as rest periods, exercise selection, loads and intensities, or the training status of the subjects could influence the training outcome. By comparing the results of numerous studies using different training methods, reasonable conclusions should be found in this paper. In addition, by considering the most relevant points tackled in the discussion section, this thesis is providing a high-quality model study design to investigate the ‘trainability’ of PAP through complex training.

Initially, it is important to note that there are some factors limiting the outcomes of this thesis. First of all, the immense diversity of the 41 studies under review delivers a broad and differentialized picture, but also results in some major limitations. Due to the differences in study design, the number and training levels of the subjects, the different durations, or exercises used, it is very difficult to come to valid conclusions. Furthermore, the overall quality of many included studies may lower their validity. However, it has to be highlighted, that the used PEDro scale may not be completely, but still best suitable for this kind of scientific studies.

One serious limitation concerning this training method in general is how it is referred to. As elaborated in chapter 2.4.1 the conflicting definitions and conceptualizations of complex training make it difficult to form a common ground for investigating this concept. Further research is necessary to both investigate the various effects of the different combination forms and to find consensus over the categorization of such training forms.

In general, the present data show that complex training forms offer a suitable training method for improving all the performance measures under review. Especially, the frequently mentioned neuromuscular adaptations, or the time efficient and varied training design stand in for this method. Only occasional accounts report a significant superiority of complex training forms over alternative training methods in strength (de Villarreal et al., 2013; Hammami et al., 2018; Stasinaki et al., 2015), sprint (Kotzamanidis et al., 2005; Radnor et al., 2017) or jump measures (Fathi et al., 2018; Hammami et al., 2018; Kotzamanidis et al., 2005; Radnor et al., 2017), but an overall tendency about the superiority over other methods cannot be recognized. The accounts for body fat percentage were too few to draw definite conclusion. For sport-specific variables the trials were also very few (5) and diverse. They do show that complex training forms have a positive effect, but only one (Lee et al., 2014) indicated significantly better results than controls or other methods. Furthermore, the influences of parameters, such as training level, used exercises or load prescriptions may be apparent, but due to the diversity of investigated studies, no clear tendencies were recognizable.

Nevertheless, the combination of different training methods may be an attractive option for trainers and athletes to efficiently increase performance in multiple areas. It appears, that especially for increasing both strength and power, complex training holds considerable benefits. In order to draw definite conclusions further research is necessary.

7 List of References

Aagaard, P., & Andersen, J. L. (1998). Correlation between contractile strength and myosin heavy chain isoform composition in human skeletal muscle. *Medicine and science in sports and exercise, 30*(8), 1217-1222. doi:10.1097/00005768-199808000-00006

Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2002). Neural adaptation to resistance training: Changes in evoked V-wave and H-reflex responses. *Journal of Applied Physiology, 92*(6), 2309. doi:10.1152/japplphysiol.01185.2001

Alemdaroglu, U., Dündar, U., Köklü, Y., Asci, A., & Findikoglu, G. (2013). The effect of exercise order incorporating plyometric and resistance training on isokinetic leg strength and vertical jump performance: A comparative study. *Isokinetics and Exercise Science, 21*, 211-217.

Almoslim, H. (2016). Effect of Combined Plyometric-Sprint and Combined Plyometric-Resistance Training Protocols on Speed, Explosive Power and Change of Direction. *Indian Journal of Science and Technology, 9*(32).

Alves, J. M. V. M., Rebelo, A. N., Abrantes, C., & Sampaio, J. (2010). Short-term effects of complex and contrast training in soccer players' vertical jump, sprint, and agility abilities. *The Journal of Strength & Conditioning Research, 24*(4), 936-941.

Arabatzi, F., Kellis, E., & De Villarreal, E. S.-S. (2010). Vertical jump biomechanics after plyometric, weight lifting, and combined (weight lifting+ plyometric) training. *The Journal of Strength & Conditioning Research, 24*(9), 2440-2448.

Arabatzi, F., Kellis, E., & Saez-Saez De Villarreal, E. (2010). Vertical jump biomechanics after plyometric, weight lifting, and combined (weight lifting + plyometric) training. *Journal of Strength and Conditioning Research, 24*(9), 2440–2448. doi:10.1519/JSC.0b013e3181e274ab

Arazi, H., Asadi, A., & Roohi, S. (2014). Enhancing Muscular Performance in Women: Compound Versus Complex, Traditional Resistance and Plyometric Training Alone. *Journal of Musculoskeletal Research, 17*(02). doi:10.1142/s0218957714500079

Baechle, T., & Earle, R. (2008). *Essentials of Strength Training and Conditioning* (3 ed.). Champaign: Human Kinetics.

Baker, D. (2003). Acute Effect of Alternating Heavy and Light Resistances on Power Output During Upper-Body Complex Power Training. *Journal of strength and conditioning research / National Strength & Conditioning Association, 17*, 493. doi:10.1519/1533-4287(2003)017<0493:AEOAHA>2.0.CO;2

Bauer, P., Uebellacker, F., Mitter, B., Aigner, A. J., Hasenoehrl, T., Ristl, R., . . . Seitz, L. B. Combining Strength and Plyometric Training: A Systematic Review and Meta-analysis of Findings from Complex Training Studies. *Unpublished manuscript*, University of Vienna.

Behm, D. G., & Sale, D. G. (1993). Intended rather than actual movement velocity determines velocity-specific training response. *J Appl Physiol (1985), 74*(1), 359-368. doi:10.1152/jappl.1993.74.1.359

Bevan, H. R., Owen, N. J., Cunningham, D. J., Kingsley, M. I. C., & Kilduff, L. P. (2009). Complex training in professional rugby players: Influence of recovery time on upper-body power output. *Journal of Strength and Conditioning Research, 23*(6), 1780–1785. doi:10.1519/JSC.0b013e3181b3f269

Brandenburg, J. P. (2005). The acute effects of prior dynamic resistance exercise using different loads on subsequent upper-body explosive performance in resistance-trained men. *Journal of Strength and Conditioning Research, 19*(2), 427–432. doi:10.1519/R-15074.1

Brito, J., Vasconcellos, F., Oliveira, J., Krustrup, P., & Rebelo, A. (2014). Short-term performance effects of three different low-volume strength-training programmes in college male soccer players. *Journal of human kinetics, 40*(1), 121-128.

Chen, Z. R., Lo, S. L., Wang, M. H., Yu, C. F., & Peng, H. T. (2017). Can Different Complex Training Improve the Individual Phenomenon of Post-Activation Potentiation? *Journal of human kinetics*, *56*, 167-175. doi:10.1515/hukin-2017-0034

Chiu, L. Z., & Barnes, J. L. (2003). The Fitness-Fatigue Model Revisited: Implications for Planning Short-and Long-Term Training. *Strength & Conditioning Journal, 25*(6), 42-51.

Chu, D. A. (1983). Plyometrics: The Link Between Strength and Speed. *Strength and conditioning journal, 5*(2).

Chu, D. A. (1998). *Jumping Into Plyometrics*. Illinois: Human Kinetics.

Cormie, P., McGuigan, M. R., & Newton, R. U. (2011a). Developing Maximal Neuromuscular Power: Part 1 - Biological Basis of Maximal Power Production. *Sports Medicine, 41*(1), 17–38. doi:10.2165/11537690-000000000-00000

Cormie, P., McGuigan, M. R., & Newton, R. U. (2011b). Developing Maximal Neuromuscular Power: Part 2 - Training Considerations for Improving Maximal Power Production. *Sports Medicine, 41*(2), 125–146. doi:10.2165/11538500-000000000-00000

Cronin, J. B., McNair, P. J., & Marshall, R. N. (2003). Force-velocity analysis of strength-training techniques and load: implications for training strategy and research. *J Strength Cond Res, 17*(1), 148-155.

Davies, G., Riemann, B. L., & Manske, R. (2015). Current Concepts of Plyometric Exercise. *International Journal of Sports Physical Therapy, 10*(6), 760–786.

Davies, T., Kuang, K., Orr, R., Halaki, M., & Hackett, D. (2017). Effect of Movement Velocity During Resistance Training on Dynamic Muscular Strength: A Systematic Review and Meta-Analysis. *Sports Med, 47*(8), 1603-1617. doi:10.1007/s40279-017-0676-4

de Villarreal, E. S., Izquierdo, M., & Gonzalez-Badillo, J. J. (2011). Enhancing jump performance after combined vs. maximal power, heavy-resistance, and plyometric training alone. *The Journal of Strength & Conditioning Research, 25*(12), 3274-3281.

de Villarreal, E. S., Requena, B., Izquierdo, M., & Gonzalez-Badillo, J. J. (2013). Enhancing sprint and strength performance: combined versus maximal power, traditional heavy-resistance and plyometric training. *Journal of science and medicine in sport, 16*(2), 146-150.

Delecluse, C. (1997). Influence of strength training on sprint running performance. Current findings and implications for training. *Sports Med, 24*(3), 147-156.

Desmedt, J. E., & Godaux, E. (1977). Ballistic contractions in man: characteristic recruitment pattern of single motor units of the tibialis anterior muscle. *J Physiol, 264*(3), 673-693.

Docherty, D., Robbins, D., & Hodgson, M. (2004). Complex Training Revisited: A Review of its Current Status as a Viable Training Approach. *Strength & Conditioning Journal, 26*(6), 52–57.

Dodd, D. J., & Alvar, B. A. (2007). Analysis of acute explosive training modalities to improve lower-body power in baseball players. *Journal of Strength and Conditioning Research, 21*(4), 1177.

Duthie, G. M., Young, W. B., & Aitken, D. A. (2002). The acute effects of heavy loads on jump squat performance: An evaluation of the complex and contrast methods of power development. *Journal of Strength and Conditioning Research, 16*(4), 530–538.

Ebben, W. P. (2002). Complex Training: A Brief Review. *Journal of sports science & medicine, 1*(2), 42–46.

Ebben, W. P., Jensen, R., & Blackard, D. (2000). Electromyographic and Kinetic Analysis of Complex Training Variables. *The Journal of Strength and Conditioning Research*, *14*, 451. doi:10.1519/00124278-200011000-00013

Ebben, W. P., & Watts, P. B. (1998). A Review of Combined Weight Training and Plyometric Training Modes: Complex Training. *Strength and conditioning journal, 20*(5), 18. doi:10.1519/1073-6840(1998)020<0018:AROCWT>2.3.CO;2

Fathi, A., Hammami, R., Moran, J., Borji, R., Sahli, S., & Rebai, H. (2018). Effect of A 16 Week Combined Strength and Plyometric Training Program Followed by A Detraining Period on Athletic Performance in Pubertal Volleyball Players. *Journal of Strength and Conditioning Research*.

Faude, O., Roth, R., Di Giovine, D., Zahner, L., & Donath, L. (2013). Combined strength and power training in high-level amateur football during the competitive season: a randomised-controlled trial. *Journal of Sports Sciences, 31*(13), 1460-1467.

Fleck, S., & Kontor, K. (1986). SOVIET STRENGTH AND CONDITIONING: Complex training. *Strength & Conditioning Journal, 8*(5), 66–72.

Fletcher, I. M., & Hartwell, M. (2004). Effect of an 8-week combined weights and plyometrics training program on golf drive performance. *The Journal of Strength & Conditioning Research, 18*(1), 59-62.

Franco-Márquez, F., Rodríguez-Rosell, D., González-Suárez, J. M., Pareja-Blanco, F., Mora-Custodio, R., Yañez-García, J. M., & González-Badillo, J. J. (2015). Effects of combined resistance training and plyometrics on physical performance in young soccer players. *International journal of sports medicine, 94*(11), 906-914.

Freitas, T. T., Martinez-Rodriguez, A., Calleja-González, J., & Alcaraz, P. E. (2017). Short-term adaptations following Complex Training in team-sports: A meta-analysis. *PLOS ONE, 12*(6), e0180223. doi:10.1371/journal.pone.0180223

Gabriel, D. A., Kamen, G., & Frost, G. (2006). Neural adaptations to resistive exercise: mechanisms and recommendations for training practices. *Sports Med, 36*(2), 133-149.

García-Pinillos, F., Martínez-Amat, A., Hita-Contreras, F., Martínez-López, E. J., & Latorre-Román, P. A. (2014). Effects of a Contrast Training Program Without External Load on Vertical Jump, Kicking Speed, Sprint, and Agility of Young Soccer Players. *Journal of Strength and Conditioning Research, 28*(9), 2452–2460. doi:10.1519/JSC.0000000000000452

González-Badillo, J. J., Marques, M. C., & Sánchez-Medina, L. (2011). The Importance of Movement Velocity as a Measure to Control Resistance Training Intensity. *Journal of human kinetics, 29A*, 15-19. doi:10.2478/v10078-011-0053-6

Greenwood, M. (2014). Complex Training Reexamined: Review and Recommendations to Improve Strength and Power. *Strength and conditioning journal*, *36*, 10–19.

Haff, G. G., & Nimphius, S. (2012). Training Principles for Power. *Strength & Conditioning Journal, 34*(6), 2-12. doi:10.1519/SSC.0b013e31826db467

Hamada, T., Sale, D. G., & Macdougall, J. D. (2000). Postactivation potentiation in endurance-trained male athletes. *Medicine and science in sports and exercise, 32*(2), 403-411. doi:10.1097/00005768-200002000-00022

Hammami, M., Gaamouri, N., Shephard, R. J., & Chelly, M. S. (2018). Effects of Contrast Strength vs. Plyometric Training on Lower Limb Explosive Performance, Ability to Change Direction and Neuromuscular Adaptation in Soccer Players. *Journal of Strength and Conditioning Research*.

Hammami, M., Negra, Y., Shephard, R. J., & Chelly, M. S. (2017a). The Effect of Standard Strength vs. Contrast Strength Training on the Development of Sprint, Agility, Repeated Change of Direction, and Jump in Junior Male Soccer Players. *The Journal of Strength & Conditioning Research, 31*(4), 901-912.

Hammami, M., Negra, Y., Shephard, R. J., & Chelly, M. S. (2017b). Effects of leg contrast strength training on sprint, agility and repeated change of direction performance in male soccer players. *The Journal of sports medicine and physical fitness, 57*(11), 1424-1431.

Hohmann, A., Lames, M., & Letzelter, M. (2010). *Einführung in die Trainingswissenschaft*: Limpert.

Jones, P., & Lees, A. (2003). A Biomechanical Analysis of the Acute Effects of Complex Training Using Lower Limb Exercises. *Journal of strength and conditioning research / National Strength & Conditioning Association, 17*, 694. doi:10.1519/1533-4287(2003)017<0694:ABAOTA>2.0.CO;2

Juárez, D., González-Ravé, J. M., & Navarro, F. (2009). Effects of complex vs non complex training programs on lower body maximum strength and power. *Isokinetics and Exercise Science, 17*(4), 233-241.

Kamal, O. (2016). EFFECT OF COMPLEX CIRCUIT EXERCISES ON CD34/CD45 STEM CELLS, CERTAIN PHYSICAL VARIABLES AND COMPOSITE SKILLFUL PERFORMANCES AMONG FEMALE KARATE PLAYERS. *Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health, 16*(1).

Kilduff, L. P., Bevan, H. R., Kingsley, M. I. C., Owen, N. J., Bennett, M. A., Bunce, P. J., . . . Cunningham, D. J. (2007). Postactivation potentiation in professional rugby players: Optimal recovery. *Journal of Strength and Conditioning Research, 21*(4), 1134–1138. doi:10.1519/R-20996.1

Knudson, D. V. (2009). Correcting the Use of the Term “Power” in the Strength and Conditioning Literature. *The Journal of Strength & Conditioning Research, 23*(6), 1902-1908. doi:10.1519/JSC.0b013e3181b7f5e5

Kobal, R., Loturco, I., Barroso, R., Gil, S., Cuniyochi, R., Ugrinowitsch, C., . . . Tricoli, V. (2017). Effects of different combinations of strength, power, and plyometric training on the physical performance of elite young soccer players. *The Journal of Strength & Conditioning Research, 31*(6), 1468-1476.

Kotzamanidis, C., Chatzopoulos, D., Michailidis, C., Papaiakovou, G., & Patikas, D. (2005). The effect of a combined high-intensity strength and speed training program on the running and jumping ability of soccer players. *Journal of Strength and Conditioning Research, 19*(2), 369.

Kramer, J., Morrow, A., & Leger, A. (1993). Changes in rowing ergometer, weight lifting, vertical jump and isokinetic performance in response to standard and standard plus plyometric training programs. *International journal of sports medicine, 14*(08), 449-454.

Kyröläinen, H., Avela, J., McBride, J. M., Koskinen, S., Andersen, J., Sipilä, S., . . . Komi, P. (2005). Effects of power training on muscle structure and neuromuscular performance. *Scandinavian journal of medicine & science in sports, 15*(1), 58-64.

Labib, H. (2013). Effect of complex training on cd34/cd45 stem cells, certain physical variables and jump shoot performance for female handball. *Medicinal Chemistry, 8*, 721-738.

Lee, C., Lee, S., & Yoo, J. (2014). The effect of a complex training program on skating abilities in ice hockey players. *Journal of physical therapy science, 26*(4), 533-537.

Lesinski, M., Muehlbauer, T., Büsch, D., & Granacher, U. (2014). Effekte von Komplextraining auf Kraft- und Schnelligkeitsleistungen bei Sportlern: Ein systematischer Überblick. [Effects of Complex Training on Strength and Speed Performance in Athletes: A Systematic Review]. *Sportverletz Sportschaden, 28*(02), 85–107. doi:10.1055/s-0034-1366145

Lloyd, R. S., Radnor, J. M., Croix, M. B. D. S., Cronin, J. B., & Oliver, J. L. (2016). Changes in sprint and jump performances after traditional, plyometric, and combined resistance training in male youth pre-and post-peak height velocity. *The Journal of Strength & Conditioning Research, 30*(5), 1239-1247.

Loturco, I., Tricoli, V., Roschel, H., Nakamura, F. Y., Abad, C. C. C., Kobal, R., . . . González-Badillo, J. J. (2014). Transference of traditional versus complex strength and power training to sprint performance. *Journal of human kinetics, 41*(1), 265-273.

Loturco, I., Ugrinowitsch, C., Roschel, H., Mellinger, A. L., Gomes, F., Tricoli, V., & Gonzáles-Badillo, J. J. (2013). Distinct temporal organizations of the strength-and power-training loads produce similar performance improvements. *The Journal of Strength & Conditioning Research, 27*(1), 188-194.

Lundin, P., Berg, W. (1991). A review of plyometric training. *NSCA Journal*(13), 69–75.

Lyttle, A. D., Wilson, G. J., & Ostrowski, K. J. (1996). Enhancing performance: Maximal power versus combined weights and plyometrics training. *Journal of Strength and Conditioning Research, 10*, 173-179. doi:10.1519/1533-4287(1996)010<0173:EPMPVC>2.3.CO;2

MacDonald, C. J., Lamont, H. S., & Garner, J. C. (2012). A comparison of the effects of 6 weeks of traditional resistance training, plyometric training, and complex training on measures of strength and anthropometrics. *Journal of strength and conditioning research / National Strength & Conditioning Association, 26*(2), 422–431. doi:10.1519/JSC.0b013e318220df79

Markovic, G. (2007). Does plyometric training improve vertical jump height? A meta-analytical review. *British Journal of Sports Medicine, 41*(6), 349. doi:10.1136/bjsm.2007.035113

McBride, J. M., Nimphius, S., & Erickson, T. M. (2005). The acute effects of heavy-load squats and loaded countermovement jumps on sprint performance. *Journal of Strength and Conditioning Research, 19*(4), 893–897. doi:10.1519/R-16304.1

McBride, J. M., Triplett-McBride, T., Davie, A., & Newton, R. U. (2002). The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed. *Journal of Strength and Conditioning Research, 16*(1), 75-82. doi:10.1519/1533-4287(2002)016<0075:teohvl>2.0.co;2

McMaster, D., Gill, N., McGuigan, M., & Cronin, J. (2014). Effects of complex strength and ballistic training on maximum strength, sprint ability and force-velocity-power profiles of semi-professional rugby union players. *J Aust Strength Cond, 22*(1), 17-30.

Mihalik, J. P., Libby, J. J., Battaglini, C. L., & McMurray, R. G. (2008). Comparing Short-Term Complex and Compound Training Programs on Vertical Jump Height and Power Output. *Journal of strength and conditioning research / National Strength & Conditioning Association, 22*, 47. doi:10.1519/JSC.0b013e31815eee9e

Mitchell, C. J., & Sale, D. G. (2011). Enhancement of jump performance after a 5-RM squat is associated with postactivation potentiation. *European journal of applied physiology, 111*(8), 1957–1963. doi:10.1007/s00421-010-1823-x

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med, 6*(7), e1000097. doi:10.1371/journal.pmed.1000097

Newton, R. U., & Kraemer, W. J. (1994). Developing Explosive Muscular Power: Implications for a Mixed Methods Training Strategy. *Strength & Conditioning Journal, 16*(5), 20-31.

Radnor, J. M., Lloyd, R. S., & Oliver, J. L. (2017). Individual response to different forms of resistance training in school-aged boys. *The Journal of Strength & Conditioning Research, 31*(3), 787-797.

Rodríguez-Rosell, D., Torres-Torrelo, J., Franco-Márquez, F., González-Suárez, J. M., & González-Badillo, J. J. (2017). Effects of light-load maximal lifting velocity weight training vs. combined weight training and plyometrics on sprint, vertical jump and strength performance in adult soccer players. *Journal of science and medicine in sport, 20*(7), 695-699.

Ronnestad, B. R., Kvamme, N. H., Sunde, A., & Raastad, T. (2008). Short-term effects of strength and plyometric training on sprint and jump performance in professional soccer players. *Journal of Strength and Conditioning Research, 22*(3), 773–780. doi:10.1519/JSC.0b013e31816a5e86

Sale, D. (2002). Postactivation Potentiation: Role in Human Performance. *Exercise and Sport Sciences Reviews, 30*(3), 138-143.

Sale, D. (2004). Postactivation potentiation: Role in performance. *British Journal of Sports Medicine, 38*(4), 386–387. doi:10.1136/bjsm.2002.003392

Seitz, L. B., de Villarreal, E. S., & Haff, G. G. (2014). The temporal profile of postactivation potentiation is related to strength level. *J Strength Cond Res, 28*(3), 706-715. doi:10.1519/JSC.0b013e3182a73ea3

Seitz, L. B., & Haff, G. G. (2016). Factors Modulating Post-Activation Potentiation of Jump, Sprint, Throw, and Upper-Body Ballistic Performances: A Systematic Review with Meta-Analysis. *Sports Medicine, 46*(2), 231–240. doi:10.1007/s40279-015-0415-7

Sheppard, J. M., & Young, W. B. (2006). Agility literature review: classifications, training and testing. *J Sports Sci, 24*(9), 919-932. doi:10.1080/02640410500457109

Smith, C. E., Lyons, B., & Hannon, J. C. (2014). A pilot study involving the effect of two different complex training protocols on lower body power. *Human Movement, 15*(3), 141-146.

Stasinaki, A.-N., Gloumis, G., Spengos, K., Blazevich, A. J., Zaras, N., Georgiadis, G., . . . Terzis, G. (2015). Muscle Strength, Power, and Morphologic Adaptations After 6

Weeks of Compound vs. Complex Training in Healthy Men. *Journal of Strength and Conditioning Research, 29*(9), 2559–2569. doi:10.1519/JSC.0000000000000917

Stone, M. H., Moir, G., Glaister, M., & Sanders, R. (2002). How much strength is necessary? *Physical Therapy in Sport, 3*(2), 88-96. doi:https://doi.org/10.1054/ptsp.2001.0102

Talpey, S. W., Young, W. B., & Saunders, N. (2016). Is nine weeks of complex training effective for improving lower body strength, explosive muscle function, sprint and jumping performance? *International Journal of Sports Science & Coaching, 11*(5), 736-745.

Tidow, G. (1994). Lösungsansätze zur Optimierung des Schnellkrafttrainings auf der Basis muskelbioptischer Befunde. In R. Brack, A. Hohmann, & H. Wieland (Eds.), *Trainingssteuerung. Konzeptionelle und trainingsmethodische Aspekte* (pp. 219-225). Stuttgart: Naglschmid.

Torres-Torrelo, J., Rodríguez-Rosell, D., & González-Badillo, J. J. (2017). Light-load maximal lifting velocity full squat training program improves important physical and skill characteristics in futsal players. *Journal of Sports Sciences, 35*(10), 967-975.

Tsimachidis, C., Patikas, D., Galazoulas, C., Bassa, E., & Kotzamanidis, C. (2013). The post-activation potentiation effect on sprint performance after combined resistance/sprint training in junior basketball players. *Journal of Sports Sciences, 31*(10), 1117-1124.

Tsimahidis, K., Galazoulas, C., Skoufas, D., Papaiakovou, G., Bassa, E., Patikas, D., & Kotzamanidis, C. (2010). The Effect of Sprinting After Each Set of Heavy Resistance Training on the Running Speed and Jumping Performance of Young Basketball Players. *Journal of Strength and Conditioning Research, 24*(8), 2102–2108. doi:10.1519/JSC.0b013e3181e2e1ed

Übellacker, F., & Bauer, P. (2017). *The combination of strength and power training to enhance athletic sports performance: A systematic review.* (Master Thesis), University of Vienna, Vienna.

Veliz, R. R., Requena, B., Suarez-Arrones, L., Newton, R. U., & de Villarreal, E. S. (2014). Effects of 18-week in-season heavy-resistance and power training on throwing velocity, strength, jumping, and maximal sprint swim performance of elite male water polo players. *The Journal of Strength & Conditioning Research, 28*(4), 1007-1014.

Veliz, R. R., Suarez-Arrones, L., Requena, B., Haff, G. G., Feito, J., & de Villarreal, E. S. (2015). Effects of in-competitive season power-oriented and heavy resistance lower-body training on performance of elite female water polo players. *The Journal of Strength & Conditioning Research, 29*(2), 458-465.

Wallenta, C., Granacher, U., Lesinski, M., Schünemann, C., & Muehlbauer, T. (2016). Effects of Complex Versus Block Strength Training on the Athletic Performance of Elite Youth Soccer Players. *Sportverletzung Sportschaden: Organ der Gesellschaft fur Orthopadisch-Traumatologische Sportmedizin, 30*(1), 31-37.

Wilson, J. M., Duncan, N. M., Marin, P. J., Brown, L. E., Loenneke, J. P., Wilson, S. M., . . . Ugrinowitsch, C. (2013). Meta-analysis of postactivation potentiation and power: effects of conditioning activity, volume, gender, rest periods, and training status. *J Strength Cond Res, 27*(3), 854-859. doi:10.1519/JSC.0b013e31825c2bdb

Young, W. B., Jenner, A., & Griffiths, K. (1998). Acute Enhancement of Power Performance From Heavy Load Squats. *Journal of Strength and Conditioning Research, 12*(2), 82–84.

Zatsiorsky, V., & Kraemer, W. (2016). *Krafttraining: Praxis und Wissenschaft*: Meyer & Meyer.

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Eidesstattliche Erklärung:

„Ich erkläre, dass ich die vorliegende Arbeit selbstständig verfasst habe und nur die ausgewiesenen Hilfsmittel verwendet habe. Diese Arbeit wurde weder an einer anderen Stelle eingereicht (z. B. für andere Lehrveranstaltungen) noch von anderen Personen (z. B. Arbeiten von anderen Personen aus dem Internet) vorgelegt."

Wien, 2018