EFFECTS OF CLUSTER VERSUS TRADITIONAL SET DURING COMPLEX TRAINING ON LOWER-BODY POWER AND STRENGTH

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UNIVERSITI PENDIDIKAN SULTAN IDRIS

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EFFECTS OF CLUSTER VERSUS TRADITIONAL SET DURING COMPLEX TRAINING ON LOWER-BODY POWER AND STRENGTH

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Author

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ABSTRACT

The aim of this study was to determine the effects of cluster set compared to the traditional set during complex training on lower-body power and strength. This quasi-experimental with pre-test and post-test designed study involved thirty subjects who were chosen via stratified random sampling. Subjects were matched according to the baseline relative power values and they were assigned into two groups of control and treatment namely Traditional Set TS (n=15) and Cluster Set CS (n=15). Both groups underwent six weeks of complex training. Power and strength parameters were measured at pre-test and post-test by the countermovement jump and 3RM squat test protocols respectively. Countermovement jumps were recorded using a slow motion video camera at 240 frame per second while the power measurements were derived via My Jump 2 application, both using the iOS 8 software on iPhone 6 smartphone. The 3RM squat measurements were performed using free weights. Both group were level in their relative power at the baseline, confirmed by the t-test [$t(28)=0.160$; $p>0.05$]. MANOVA analysis was used to determine the effects of both type of training within the specified time. No significant interaction of time*group were found [$F(6,23)=0.23$, $p>0.05$]. However, mean differences were detected between the relative power sub-component of the treatment group ($M=32.28$; $SD=4.54$) and the control group ($M=31.85$; $SD=5.03$). Mean differences were also detected for jump height between the treatment group ($M=42.20$; $SD=5.32$) and the control group ($M=40.89$; $SD=5.11$). In conclusion, the cluster set training method produced slightly better performance improvements for jump height and relative power compared to the traditional set method. The study implicates that the use of cluster set during complex training can be practiced to train youth athletes to improve lower-body power and strength.

KESAN SET KLUSTER BERBANDING SET TRADISIONAL SEMASA LATIHAN KOMPLEKS TERHADAP KUASA DAN KEKUATAN BAWAH TUBUH

ABSTRAK

Kajian ini dijalankan untuk menentukan kesan set kluster berbanding set tradisional semasa latihan kompleks terhadap kuasa dan kekuatan bawah tubuh. Kajian yang menggunakan reka bentuk kuasi-eksperimental dengan ujian pra dan pos ini melibatkan tiga puluh orang peserta yang dipilih secara rawak berstrata. Peserta dipadankan berdasarkan bacaan awal kuasa relatif dan mereka telah dibahagi kepada dua kumpulan iaitu kumpulan kawalan Set Tradisional TS (n=15) dan kumpulan rawatan Set Kluster CS (n=15). Kedua-dua kumpulan menjalani latihan kompleks selama enam minggu. Parameter kuasa dan kekuatan diukur ketika ujian pra dan pos melalui protokol ujian lompatan *countermovement* dan ujian *squat* 3RM. Lompatan *countermovement* dirakam menggunakan kamera gerak perlahan pada 240 bukaan per saat manakala ukuran prestasi kuasanya diperoleh melalui aplikasi *My Jump 2,* kedua-duanya menggunakan perisian *iOS 8* pada telefon pintar *iPhone 6*. Ukuran 3RM *squat* dilakukan menggunakan alatan bebanan *free weights.* Kedua-dua kumpulan adalah setara dalam aspek kuasa relatif ketika permulaan kajian dan ianya disahkan melalui ujian-t [t(28)=0.160; p>0.05]. Ujian *MANOVA* pula digunakan untuk menentukan kesan kedua-dua jenis latihan dalam jangka masa yang telah ditetapkan. Tiada interaksi signifikan antara masa*kumpulan yang telah ditemui [F (6,23)=0.23; p>0.05]. Namun terdapat perbezaan min bagi sub komponen kuasa relatif di antara kumpulan rawatan (M=32.28; SP=4.54) dan kumpulan kawalan (M=31.85; SP=5.03). Perbezaan min juga dikesan untuk ketinggian lompatan di antara kumpulan rawatan (M=42.20; SP=5.32) dan kumpulan kawalan (M=40.89; SP=5.11). Kesimpulannya, kaedah latihan set kluster menghasilkan peningkatan prestasi yang sedikit tinggi untuk ketinggian lompatan dan kuasa relatif berbanding kaedah set tradisional. Implikasi kajian menunjukkan penggunaan set kluster semasa latihan kompleks boleh dipraktikkan untuk melatih atlet belia bagi meningkatkan kuasa dan kekuatan bawah tubuh.

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LIST OF ABBREVIATIONS

BOX	BOX JUMP
CMJ	COUNTERMOVEMENT JUMP
CS	CLUSTER SET
IRR	INTER-REPETITION SET
PAP	POST-ACTIVATION POTENTIATION
RDL	ROMANIAN DEADLIFT
RM	REPETITION MAXIMUM
SCR	STANDING CALF RAISE
SJ	SQUAT JUMP
SQ	SQUAT
TJ	TUCK JUMP
TS	TRADITIONAL SET

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In team sports, power and strength are crucial factors to maintain and achieve performance (Zhang, Quan, & Cao, 2019). The ability to optimize muscular strength and neuromuscular power is fundamental to successful performance in these sports. Most of the athletes need to maintain a high capacity of velocity in the sport-specific movement to ensure the achievement of a high level performance (Cormie, McGuigan, & Newton, 2011; Cronin & Sleivert, 2005).

Power can be described as the rate of doing work (McGuigan, 2017). Meanwhile, Turner (2009), Adams, O'Shea, O'Shea and Climstein (1992) states that power represents the amount of work a muscle can produce per unit of time. Besides, power is also described as force multiplied by velocity (Kawamori & Haff, 2004; Haff et al., 2003).

In the development of higher power and strength, several modalities of training methods have been used such as resistance training (Boullosa, Abreu, Beltrame, & Behm, 2013; Izquierdo, 2006; Baker, 2003), plyometrics (Asadi & Arazi, 2012; Meylan & Malatesta, 2009; Thomas, French, & Hayes, 2009), ballistic training (Winchester et al., 2008; Newton, Kraemer, & Häkkinen, 1999) and complex training (Argus, Gill, Keogh, McGuigan, & Hopkins, 2012; Comyns, Harrison, & Hennessy, 2010; Baker & Newton, 2005; Fatouros et al., 2000)

Complex training is recognised as one of the training method which can be implemented in a training program to enhance power and strength, involves a combination of a heavy load exercise followed by a biomechanically similar explosive activity (Weber, Kurt, Brown, Lee, Coburn, Jared, & Zinder, Steven, 2008; Docherty, Robbins, & Hodgson, 2004). A complex training session consists of heavy loads of resistance training followed by a series of lighter loads plyometrics to produce power (Tufano, Brown, & Haff, 2016; Ebben, 2002).

The central focus of complex training is the stimulation of motor unit excitability to increase power output. In complex training, increases of power and strength are caused by the simultaneous work of the activated motor units (Lim & Barley, 2016 Carter & Greenwood, 2014). Practically, using heavy loads in resistance exercises can increases motor neuron excitability and reflex potentiation thus possibly enhancing neuromuscular power (Ebben & Watts, 1998). Conversely, lighter loads in plyometric training with higher movement velocity can increase the rate of force development and maximal power production (de Hoyo et al., 2016; Ramírez-Campillo et al., 2015; Baker, 2003).

A comparative study on power training modalities by Adams et al. (1992) indicated that a combination of plyometrics and resistance training in the same session is superior to the separated regime to improve jumping performance. Meanwhile, Fatouros et al. (2000) provided evidence that the complex training group produced significant improvements in vertical jump performance compared to the plyometrics and weight training group after a 12 week training program. Furthermore, Duthie, Young, and Aitken (2002) found that complex training improved power outcome. Meanwhile, in a study conducted by Mihalik, Libby, Battaglini and McMurray (2008), they observed that short term of complex training improved jump heights substantially.

In designing a complex training program, several factors such as choice of exercise, training load, number of repetitions and sets performed, exercise order, frequency and rest length periods must be considered to optimize the targeted training outcomes (Haff & Triplett, 2016; Jeffreys & Moody, 2016; Bompa & Haff, 2009). However, previous studies concluded that heavy load exercise not only produces post-activation potentiation (PAP) but also induces muscular fatigue (Kilduff et al., 2008). This has been suggested as a factor interfering with muscular output development (Tidow, 1990).

Moreover, Tufano et al. (2016) stated that the quality of performance in the subsequent repetitions in the set decreases, due to fatigue in implementing one set of successive repetitions. Usually, this response may be beneficial as fatigue may stimulate the adaptation of the neuromuscular system, resulting in a supercompensatory response. However, in other cases, the accumulated fatigue may be detrimental to the training or performance adaptations.

If complex training is not planned carefully, accumulated fatigue may occur and impair performance adaptation. In these instances, the ability to recover and maintain repetition performance would be vital (Tufano et al., 2016). Since the number of repetitions, training load and rest periods contained within a set can be manipulated to alter the training stimulus (Tufano, Brown, et al., 2017), various attempts have been made to create a training set that can maintain the repetition performance with less fatigue. Hence, the structure, configuration of the set and inter- repetition rest (IRR) has been extensively studied in plyometric and resistance training (Tufano et al., 2016), but not in the complex training where more foci has been directed to the inter-phase rest period (Tredrea, 2017).

This situation has resulted in a lack of data in the area of study for complex training. This gap indeed needs to be addressed to shed some light for the body of knowledge and sports practitioners with new empirical answers. Therefore, the present study is focused on manipulating the IRR of complex training to enhance power performance.

1.2 Problem Statement

Complex training is a combination of resistance and plyometrics training, done in one same session. It is a method used to enhance both strength and power in the same session, thus providing an efficient training (Carter & Greenwood, 2014). Hence, the challenge among sports practitioners is finding a method to improve the outcome of complex training. To optimize the performance outcome of any physical training, variables such as the number of set and repetition, training load, exercise type and rest period can be manipulated (Tufano et al., 2016; Bompa & Haff, 2009).

Among those stated variables, the rest period within a set is one of the most critical parts in ensuring the athletes to perform at the maximum level (Tufano et al., 2017). One method to utilise the rest period within a set is the cluster set (CS) configuration. CS training set is completed with inter-repetition rest (IRR), meanwhile traditional set (TS) is performed in sequence without it (Tufano et al., 2016; Boullosa et al., 2013; Haff et al., 2003).

Previously CS has been tried in several training methods, including resistance training (Haff et al., 2016). Conceptually, the IRR within a resistance training with CS configuration may yield maximized individual repetitions performance while reducing fatigue (Tufano et al., 2016; Tufano et al., 2016; Boullosa et al., 2013; Hansen, Cronin, Pickering, & Newton, 2011). CS is postulated to provide better recovery to enhance the physiological preparedness and ultimately improve performance; proven by the results from the previous studies on resistance training (Tufano et al., 2017; Tufano et al., 2017a, 2017b; Tufano et al., 2017; Nicholson, Ispoglou, & Bissas, 2016; Arazi & Bagheri, 2013; Boullosa et al., 2013; Iglesias-Soler et al., 2012; Lawton et al., 2004).

This premise is in line with the fact that it takes about 20 to 48 seconds to replenish ATP-PC up to 50%, 40 – 90 seconds to replenish 75% and 60 to 144 seconds to replenish up to to 87% of full ATP-PC restoration (Fleck & Kraemer, 2014). It is also supported by the National Academy of Sports Medicine (NASM), (2017) where the recovery period in an intermittent exercise is brief, and a complete recovery of ATP-PC cycle is approximately 90 seconds.

CS also had been tried in plyometrics. Unfortunately, to date only a limited number of studies have been conducted by Aminaei, Yazdani, and Amirseifadini (2017), Asadi and Ramírez-Campillo (2016), and Moreno, Brown, Coburn, and Judelson (2014), and have used this method. Summarising all of their findings, it was concluded that CS plyometrics has resulted in a positive improvement in jumps, agility, take–off velocity and explosive power. The concepts of TS and CS in plyometrics are similar as when applied to resistance training, where CS is associated with alleviating fatigue to provide better and quicker preparedness compared to TS. The difference is in the movements; plyometrics requires the athletes to perform jumping, bounding, hops and/or throwing to develop power (Haff et al., 2016; Jeffreys & Moody, 2016; Thurgood, 2016).

In another study, the effectiveness of CS and TS was compared during acute complex training procedures (Boullosa et al., 2013). Vertical jump performance improved after one minute using CS, compared to nine minutes using TS in a single session. However, the IRR has only been applied during the resistance phase. Treeraj, Kamutsri, Lawsirirat, and Intiraporn (2016) in their study, also used the IRR in the resistance phase, to find the best complex training variation that matches the intensities of a soccer game. Until now these are the studies applying CS in complex training, which focuses only on the instant effect.

Theoretically, the IRR implemented during the resistance phase of an incomplete CS has enhanced both the resistance and the plyometrics phases of the complex training. Faster readiness for the subsequent plyometrics phase plus the increased maximal executions level of both resistance and plyometrics phases might allow higher performance increment after each session. Hence, accumulated positive improvement is another possibility if a complete CS is carried out for a

longer training period, but that can only be proven through further research. Regarding the training period, there were abundant of proof that meaningful improvements of power and strength can be detected within six weeks of training time frame (Dorrell, Smith, & Gee, 2020; Firdaus et al., 2018; Thompson et al., 2017; Nicholson et al., 2016; MacDonald, Lamont, & Garner, 2012; MacDonald, Lamont, & Garner, 2011; Alves, Rebelo, Abrantes & Sampaio, 2010), compared to the smaller amount of supporting literature suggesting less training weeks (Morales-Artacho, Padial, García-Ramos, Pérez-Castilla, & Feriche, 2018; Mihalik, Libby, Battaglini, & McMurray, 2008).

However none of the listed literature had involved the IRR manipulation in both phases of the complex training. Before this present study, adding IRR had only been tried in resistance, plyometrics, and part of the complex training, but not in the whole complex training yet. Accordingly, given all the limitations in the literature, an attempt to investigate the effects of CS compared to the TS within six weeks of complex training regime to improve power and strength components is clearly warranted.

1.3 Objectives of The Study

The objective of this study is to investigate the effects of six weeks of a complex training program using traditional and cluster sets on power and strength among team sport athletes (soccer, futsal and hockey) of Universiti Pendidikan Sultan Idris (UPSI). The specific objectives of this study are as follows;

i. To compare the effects of traditional and cluster sets on power parameters (Countermovement jump height, flight time, velocity, force, power and relative power).

ii. To investigate the effects of traditional and cluster sets on strength. (1RM squat strength estimation from 3RM squat procedure)

1.4 Hypotheses of The Study

To achieve the study objectives the following hypotheses were formulated:

Hypothesis 1:

Null Hypothesis (H_o1): No significant differences are expected in the power parameter between traditional and cluster sets groups after 6 weeks of complex training program.

Hypothesis 2:

Null Hypothesis (H_o2): No significant differences are expected in strength between traditional and cluster sets groups after 6 weeks of the complex training program.

1.5 Theoretical Framework

In this present study, the possible increase in total performance not only could be explained by the Supercompensation Theory, but it was also postulated to be due to a carefully planned and designed training program. After receiving the overload stimulus during each of the complex training session, fatigue occurred and was accompanied by the activation of a mechanism that led to an enhanced protein synthesis. The correct scheduled post-exercise resting time should provide optimal recovery period between the complex training sessions thus allowing fatigue to dissipate and stimulate the recovery-adaptation process.

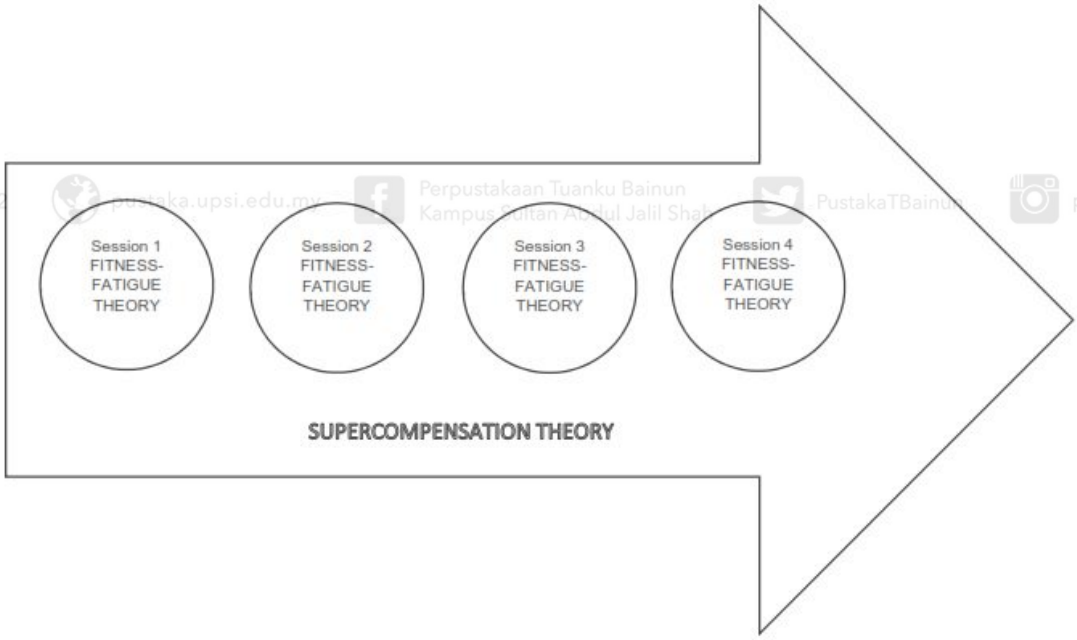

Figure 1.1. Theoretical framework of the study

Returning back to the training 'on time' allowed the supercompensation to take place. Had the sessions being scheduled closer, the recovery-adaptation might be incomplete and supercompensation would never occur. On the other hand, the immediate after-effects in each training session could have provided adequate

preparedness within both the cluster set and traditional set groups, thus affecting the inter-session adaptation which eventually accumulated in the form of an uplifted total performance. In this present study, it was postulated that the addition of the inter repetition rest would elevate the preparedness level to a higher level in the cluster set group. The intertwined relation of both theories within the scope of this present study is depicted in Figure 1.1.

1.6 Significance of The Study

This study should provide the body of knowledge with specific answers regarding to the effectiveness of implementing the cluster set on complex training, in improving power performances and lower body strength. Hence CS might be considered as one of the power training mode for the physical preparation of the athletes, should it has resulted with benefit of triggering significant mechanical and physiological mechanism compared to the traditional set, thus might allow the athletes to gain a more diverse and complete adaptation.

Also, this research would extend and expand the strength and conditioning knowledge, by forging the cluster set procedures into a complex training and testing the effectiveness of the new CS complex training. Furthermore, the use of the cluster set during the complex training might also possess a psychological advantage of being thought to be ‘easier’ than a traditional set for their less number of continuous repetitions. This ‘easier’ than traditional set feelings might promote a better self-motivation during prolonged training periods and could eventually resulted in a better training adherence.

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The findings from this present research could also be shared as the referral value for the sports practitioners throughout the nation, especially teachers and coaches in Perak who might use the My Jump 2; an award winning application using the iOS 8 software on iPhone 6 smartphone, as the measurement tools; since the present study had used this tool to yield the data related to power. This may help them avoid biased comparison against data gathered from the laboratory devices such as force plates and transducers.

Added to that, as laboratory devices are not freely accessible to everyone, the procedures of this present study and the gathered data from it may provide easy guidelines and option for sports practitioners to conduct this field test and use the same My Jump 2 application. It might help them to overcome the difficulties of using lab based equipments. Otherwise sports practitioners might only rely on other orthodox jumping test which usually provide jump height data alone, which had been argued as insufficient to be a good indicator for the lower limb power output (Morin, Jiménez-Reyes, Brughelli, & Samozino, 2019). Of course they can still calculate the power related measure manually from the jump height data, but the automatic calculation from the My Jump 2 application combined with the reference data from this present study, would save a large amount of time.

Finally, areas that were not covered by this present study would always provide new gaps to be fulfilled later by other future researchers. It could serve as the base issue to be replicated or extended and tested to other population and variables.

1.7 Limitations

The limitations of this present study are the subject attrition, confounding variables, interaction between groups, instruments' accuracy and method used. These factors however were addressed carefully by the present researcher so it did not affect the findings to a greater degree. Subject attrition might affect the minimum sampling size thus lowering the power for this study. Hence, a conservative act is to add two more subject per each group than the required minimum sampling size.

On the other hand, potential confounding variables such as weather, health and training status, injuries, nutrition intake and extra individual training may lead to bias. To address the effect of the environmental conditions, the training sessions and test were conducted at similar time and weather within the same compound (gym). For health status and injuries limitations, they were addressed using two measures that are the screening process and the monitoring process. Health and injury screening was done by the Par-Q questionnaires before the training began, while the monitoring was done throughout the study period.

Health and injury monitoring was done visually (body language, injury signs and symptoms) and verbally (rate per exertion, current feelings and condition) by the researcher with the subjects monitoring their own heart rate (self-palpitation). For diet, nutritional and drugs consumptions, the subjects were briefed to avoid any drugs and alcohol for the whole study period while legal stimulants such as caffeine were prohibited at least 24 hours before the training and/or the test session. They were also asked to complete the diet log/diary.

The push-off distance of the subjects had surely confounded the observed power performance outcome. Rather than asking the subjects to jump at a standardized knee angle and/or fixed push-off height, the researcher had utilised the optimal push-off distance where the subjects used their individual freely self-determined jump depth. It is vital for the researcher to state here this factor had been addressed efficiently during the familiarisation week where the subjects had rehearsed their optimal push-off distance before a test-retest reliability check, resulted in a strong correlation.

This highly reproducibility of the push-off distance (countermovement jump's depth) had brought these conclusions; there should not be substantial errors in the readings of the My Jump 2 application (Pedro Jiménez-Reyes, Pierre Samozino, Fernando Pareja-Blanco & Víctor Cuadrado-Peñafiel, Juan José González-Badillo, 2017).

Another possible limitation in this present study was the subjects from the different groups might learn from each other, thus reducing the internal validity. The solution was to conduct the training for different group on separated days and they were not informed on which group was receiving the control or treatment. Since they followed the training scheme on the day, and were monitored by the researcher it was quite difficult for them to purposely implement the training protocol of the other group during the sessions although they might had learn from each other.

Added to all those limits, simple random group assignments was not practically applicable in this present study. Instead, a random match-paired group assignment was utilised. However, based on a quote; “A good enough principle of sampling, however would allow generalization to any population for which the sample is representative enough” (Serlin, 1987, p. 366). The sampling might still be adequate to be generalized to populations with similar characteristics.

The limited ability of the instruments were addressed by mentioning that the result of the present study should only be taken as a reference measure for those who are using the same device and/or tools. Furthermore it’s beyond the researcher’s reach in term of time given, funding and control to use more than the stated instruments.

Yet, with the alpha level set at 0.05, it was realistic enough to assure that readers would be confident, that all of the stated confounding effect had only affected the result at a small fraction of not more than 5% (Creswell, 2014). The researcher must accept that one study can’t solve all possible issues related to this study.

1.8 Delimitations

Delimitations made by the researcher and their reasons is the point of discussion in this section. Complex training set and rest configuration had been chosen as the topic since research in this area is still limited (Adib, Asmadi, & Tufano, 2019; Freitas, Martinez-Rodriguez, Calleja-González, & Alcaraz, 2017; Tufano et al., 2016). Consequently the training variables to be manipulated in the present study were

sets, rest time and continuous repetitions. As the inter-repetition rest was added, the number of continuous repetition per set for both resistance and plyometrics phase will also change and eventually will result as a new type of set namely cluster set.

Cluster set had been examined in the present study whether it was really effective in alleviating fatigue and provide better performance as the result from better preparedness. Hence, Supercompensation Theory and Fitness-fatigue Paradigm were also chosed for they were the most related theory to explain the wisdom in restructuring the rest and sets for the complex training.

The subjects selection of the male sports science students aged 20-22 from the Universiti Pendidikan Sultan Idris had suited the fact that the result from the present study can be generalized to a similar population. Serious injuries and repeated absence would impair supercompensation, jeopardize the data and ultimately affect the study negatively. Subjects' absence for more than three times (20%) were excluded from the program.

Countermovement jump's height, flight time, force, velocity, power, relative power estimated 1RM squat strength were the chosen dependent variables since they were related to the training benefits/purpose and could be practically measured by the instruments that the researcher had access to.

1.9 Operational Definitions

The operational definitions explains the variables used and how they are measured based on the context of the study (Thomas et al., 2015). These are the operational definition used in this study.

1.9.1 Set

As Bompa and Haff (2009) had defined, set is the number of cycle of repetition completed during exercise. (Baker, 2003). Set is a sub-set of the training volume and it is associated with the training stimulus. In this study, one set is defined as completed repetitions of one type of exercise.

1.9.2 Traditional Set (TS)

Traditional set is a complete set without any rest between the repetitions (Tufano et al., 2016). In this study TS is a set structure of physical conditioning exercise in which no rest allowed within a set.

1.9.3 Cluster Set (CS)

Cluster set is a set that includes inter repetition rest (IRR) within a set (Tufano et al., 2016). In this study CS is defined a set structure in which rest periods are added in each phase of the complex training.

1.9.4 Inter-Repetition Rest (IRR)

Inter-repetition rest (IRR) is defined as rest intervals that are applied between individual repetitions within a single set (Tufano et al., 2016). In this study IRR is defined as rest intervals that are applied between repetitions for both resistance and plyometrics phases within a single complex training set. It's measured in seconds.

1.9.5 Resistance Training

Resistance training is a specialised method of conditioning whereby and individual is working against a resistive load including body weight, weight and pneumatic resistance machines, free weights (barbells, dumbells and kettlebells), elastic bands and medicine balls (Jeffreys and Moody, 2016). In this study, resistance training is defined as a physical conditioning exercise using free weights and/or weight machines. It is measured by repetitions, set and load.

1.9.6 Plyometrics

Plyometrics is a group of high intensity, shock based activities aimed at enhancing high rates of force production, eccentric control and power (Jeffreys and Moody, 2016). In this study, it is defined as a physical conditioning using explosive jumps, hops, bounds and/or throws. It is measured by repetitions, set and load.

1.9.7 Complex Training

Complex training generally involves the execution of a resistance-training exercise using a heavy load followed by a relatively quicker and lighter load of a biomechanically similar plyometric exercise (Docherty, et al, 2004). In this study, complex training is defined as a combination of resistance and plyometrics training in a single session. One set of complex training contains one phase of resistance training and a subsequent phase of plyometrics.

1.9.8 Power Related Performance

Power can be described as the rate of doing work (McGuigan, 2017). In his study, jump height, flight time, force, velocity, power and relative power is defined as power related performance, measured simultaneously using the CMJ by the iPhone 6 recording and My Jump 2 application readings.

1.9.9 Strength

Strength is the amount of force a muscle can produce in a single effort (Jeffreys & Moody, 2016). In this study, strength is the value of the estimated 1RM, derived from the 3RM of weight lifted during a squat measured using a free weight, represented in the kg unit.