The effects of six weeks of in-season specific training on young Swedish division 2 basketball players.

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The Swedish School of Sport and Health Science
Bsc Dissertation 64: 2010
Sports Science and Coaching 2008-2011
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Acknowledgement

Firstly, we would like to express our deepest gratitude to Daniele Cardinale for his support, guidance and knowledgeable advice throughout the whole working progress. Many thanks also to Karin Söderlund, for her support and guidance with this dissertation. Also thanks are extended to Johnny Nilsson, Alexander Ovendahl and Mårten Fredriksson at LTIV for sharing their experience and the use of the laboratory equipment at our behest. Special thanks also to Annica Bergström at Farsta Gymnasium for giving us the opportunity to make use of their gym equipment. Last but not least we wish to thank the coaches and players of both groups for their willingness, cooperation and compliance throughout this project.

Abstract

Aim:

This study aims to evaluate the physiological effect of periodized specific strength training on young Swedish division 2 basketball players.

Method:

13 male basketball players of 14-21 years of age were assessed before and after a six week specific training intervention of squats, plyometrics and repeated shuttle sprints. The test battery was made up of jump and sprint tests. The jump tests included the Squat jump (SJ), Counter movement jump (CMJ_a), Drop jump (DJ) 20, 40, 60 cm, five jump for distance test (5JT), weighted jump squats (JS) with 50, 100, 200 % of body weight. Run test battery consisted of the T-test, repeat shuttle sprint ability test (RSSA) and the Yo-Yo intermittent recovery test level 1 (YY IR1). Seven of the subjects made up the intervention group (IG) and six made up the control group (CG). Both groups participated in their regular sports practice, additionally the IG performed two weekly sessions incorporating specific training.

Results:

The IG improved significantly in SJ, CMJ_a, DJ 20, T-test, RSSA and the YY IR1 ($p < 0,05$). The CG results decreased in all test parameters except in JS and T-test although the increases in the test results were not found to be significant.

Conclusions:

The conclusion to the study was that an intervention of specific training yields positive results in young basketball players. The results garnered from the intervention verify that this type of training may influence in season progress as well as being a time effective training tool for strength and conditioning specialists.

Sammanfattning

Syfte:

Syftet med studien är att utvärdera de fysiologiska effekterna av en specifik periodiserad styrketräning på unga svenska basketspelare i division 2.

Metod:

13 manliga basketspelare mellan 14-21 år gamla testades före och efter en sex veckor lång träningsintervention bestående av knäböj, plyometriska övningar och upprepade sprinter. Testbatteriet bestod av hopp och sprinttester. Hopptesterna bestod av squat jumps (SJ), counter movement jump (CMJa), drop jump (DJ) 20, 40, 60 cm, fem horisontella hopp (5JT), belastad jump squat (JS) med 50, 100, 200 % av kroppens vikt. Testbatteri för sprinterna bestod av T-testet, repeated shuttle sprint ability (RSSA) och Yo-Yo intermittent recovery test nivå 1 (YY IR1). Interventionsgruppen (IG) bestod av sju spelare och kontrollgruppen (CG) utgjordes av sex spelare. Deltagarna i båda grupperna deltog i sina vanliga basketträningar. IG genomförde utöver den vanliga basketträningen två träningar i veckan av specifik träning.

Resultat:

IG gjorde signifikanta förbättringar ($p < 0,05$) i SJ, CMJa, DJ 20, T-Test, RSSA och YY IR1 mellan för och eftertest. CG resultat minskade i alla testparametrar förutom JS och T-test där förbättringar ej funnits vara signifikanta.

Slutsatser:

Slutsatsen av studien var att en intervention bestående av specifik träning ger positiva resultat på unga basketspelare. Resultaten från träningsinterventionen verifierar att denna typ av träning kan påverka träningsresultaten positivt under säsongen samt vara ett tidseffektivt träningsredskap för styrke och konditionsspecialister.

Index

Background 1
Introduction 1
Previous research 3
Aerobic Anaerobic Training 3
Sprints 3
Strength 5
Plyometrics 7
Post activation Potential 9
Complex Training 10
Aim and Questions 10
Method 11
Literature Study 11
Subjects 11
Intervention group (IG) 11
Control group (CG) 12
Training Intervention 12
Test methodology 14
Procedure 17
Squat jump (SJ) 17
Counter movement jump free arm swing (CMJa) 17
Optimal drop jump (ODJ) 17
5 jump test (5JT) 18
Jump Squat (JS) 18
200 % of bodyweight (200 % bw) 18
T-test 18
Repeated shuttle sprint ability 19
Yo-Yo intermittent recovery test level 1 19
Statistical Analysis 20
Validity and Reliability 20
Results 22
Discussion 25
Conclusion 28
Practical Applications 29
Reference List 30

Background

Basketball was invented in 1891 by the physician and priest Doctor James Naismith at the behest of his immediate superior. He was tasked with organizing a sporting pastime that would be suitable for indoor play during the long winter months (Larsson 1998, pg.7). Basketball at the time started with two teams of nine players with a basket fastened to a wall, and once a basket was scored a ladder was needed to climb up in order to retrieve the ball, from this one can imagine that the sport was rather slow moving. It the year 1897 the members of each team were reduced to the now standard five. But it was not until the 1950s that basketball became a major college sport, which in turn raised interest in professional basketball per se.

Introduction

Basketball as a sport is multi-dimensional in the way that an athlete needs not only speed but agility power and strength, all of which takes a toll on the energy systems of the body. Analysis of the sport has revealed that sprints in average, occur every 21 s lasting 2-3 s. (McInnes, Carlson, Jones & McKenna 1995, pg. 394-396). Modern day basketball in comparison to the sports early beginnings is a fast paced dazzling spectacle of athletic mastery. But the question that needs to be answered is what type of training should be used in order to compete at top level. To play a sport at an intense level one naturally has to be strong, this being the case strength training should be a prerequisite for any and all sporting endeavors. A physical analysis of basketball confirms that basketball players require a combination of power and maximal strength so as to excel physically within the game (ibid, pg. 388-390)

Basketball games are played over four quarters of 12 minutes in the National Basketball Association (NBA) and 10 minutes under International Basketball Federation (FIBA) rules. A match in itself takes longer than this due to the game being played with stop time, meaning that the 40 to 48 minutes of the game are effective playing time. There is a two min break after the first and third period then a fifteen minutes half-time break. Minute breaks are given whenever one of five time outs are taken under FIBA’s rule. An NBA coach has the option to have eight time-outs (ranging 20 to 100 s in length) throughout an entire game. The total distance covered during a basketball game played by high school or college players may vary from 5.5 km up to 8 km with the athletes spending approximately 45 % of the game at high to moderate intensity levels. The average heart rate (HR) in games is reported to be over 90 % of maximum HR with as much as 20 % of the game time being spent at 95 % of maximum HR (Abdelkrim, El Fazaa & El Ati 2007, pg. 70; Abdelkrim, Castagna, Jabri, Battikh, Fazaa & El Ati 2010 pg. 2335; Oba & Okuda 2008, pg. 206-208). The average sprint speed during games by Asian high school and college players in meters per second (m/s) was 7 to 7.5 m/s (Oba & Okuda 2008, pg. 206-208). This leads to the fact that a great tax is put upon the anaerobic system. Almost a thousand changes of modes of movements occur every game (jogging, jumping, side runs, back peddling and sprints etc). Sixty percent of basketball games when noted revealed that on average that the aerobic system is also taxed at low to medium intensity (McInnes et al. 1995, pg. 394-95). The high intensive work has a ratio of 1 to 4, with 1 pertaining to very high intensity and 4 pertaining to middle or low intensity of duration of movement (ibid, pg. 394-396). Time motion analysis has also revealed that players sprint at an average of 3 s maximum in duration (Abdelkrim, El Fazaa & El Ati 2007, pg.70). Thus explaining the need for aerobic capacity so as to aid in recovery between bouts of sprints, which rely heavily on strength (anaerobic). This leads one to assume that basketball is an intense game with many short bursts of speed interspersed with many low tempo movements (jogs, walks, standing) due to the games intermittent nature (Bompa 2009, pg. 122). There is therefore a need for specific training of both anaerobic systems (alactic/lactic) in basketball due to the sports intermittent nature and the aerobic system due the need for recovery between bouts of high intensity work (ibid, pg. 122).

Jumping is an essential ability to gain an advantage in basketball whether the athletes are tearing down rebounds, shooting jump shots or laying in lay-ups. During a game the average of jumps is 44 times (McInnes et al. 1996, pg. 396) with the tested counter movement jump with arm swing (CMJ_a) height ranging between 50-70 cm (Latin, Berg & Baechle 1994, pg. 216; Hoffman, Tenenbaum & Maresh 1996, pg. 68; Ostojic, Mazic & Dikic 2006, pg. 741-742). As mentioned before there are over a thousand changes of movement during a game. These movements include walking, jogging, running, sprinting, shuffling at low to high intensity and jumping verticaly (McInnes et al. 1996, pg. 391). The ability to instantly and explosively change direction under controll is the factor that separates the Michael Jordans from the rest.

Previous research

Aerobic Anaerobic Training

Basketball as a sport is not purely aerobic per se, since heart rates can exceed up and above 90% on average of maximal heart rate for extended periods of time (Abdelkrim et al. 2010, pg. 926-927). This would mean the aerobic ability to recover during sprint bouts, due to the sports intermittent nature is of great importance (Bompa 2009, pg. 122). Many forms of aerobic and anaerobic training have been tested and used to improve an athlete's endurance levels such as repeated sprint ability (RSA). RSA pertains to an athlete being able to replicate maximal sprints of short duration with short recovery periods. Studies conducted on basketball players to garner which mode of recovery is more appropriate to lessen fatigue, have revealed that an active recovery hinders repeat performance of sprints and that passive recovery enabled better repeated performance (Castagna, Abt, Manzi, Annino, Padua & D'Ottavio 2008, pg. 926-927). This has been tested in intermittent sports whereby the necessity to sprint repeatedly is an essential part of game play, taxing both the aerobic and anaerobic systems thus improving overall endurance and repeated sprint ability (Ferrari Bravo, Impellizzeri, Rampinini, Castagna, Bishop & Wisloff 2008, pg. 671-672). This is an integrative part of the sport. Playing basketball at high intensity would lead to high measures of blood lactate concentrations, so repeat sprints as a training tool would make it a viable means for building lactate tolerance in basketball players thus increasing a player's ability to play at the same intense level repeatedly throughout a game (Castagna, Manzi, D'Ottavio, Annino, Padua & Bishop 2007, pg. 1174-1175). A valid tool for assessment of young basketball player's specific endurance and aerobic fitness is the Yo-Yo intermittent recovery test-level 1 (YY IR1), (Castagna, Impellerzzeri, Rampinini, D Ottavio & Manzi 2007, pg. 4-6).

Sprints

A basketball court is 28 m in length and the sport is intermittent in nature spliced with short recovery periods, in power plays an athlete will mostly accelerate and decelerate in sprinting which requires a great deal of power. Power pertaining to the ability to exert as much force as possible in the shortest amount of time (P (W) = force (N) per velocity (m/s)). Time-motion analysis of team and intermittent sports has revealed that decisive moments in a match are often preceded by short, high-intensity sprints in the range of 10-30 m or 2-4 s (Spencer, Bishop, Dawson & C 2005, pg. 1027-1028). Basketball is filled with accelerative sprints. Accelerative pertains to the rate of change of velocity over time. In the accelerative mode of a sprint the optimal body position for accelerating is a forward leaning position of approximately 45 degrees from the ground (Frye 2000, pg. 38). The forward leaning position allows the athlete to make use of the powerful hip extension muscles so as to apply force directly into the ground in order to propel the body horizontally forward (Young, Benton & Pryor 2001, pg. 8-9). This coupled with proper sprint mechanics/technique i.e. A-skip, B-skip, butt kicks and other various sprint technique drills can produce better sprint economy (Frye 2000, pg. 36-37).

There have been a plethora of articles combining sprinting with resistance training programs (ex. 5 sets of 8–5 repetition maximum (RM) half squat with a 30 m sprint after each set) in order to improve speed and jump height within basketball. These articles are based on the idea that if an athlete is strong he/she can transfer the accumulated strength with sprint training into force/power thereby increasing all measured parameters within basketball i.e.1RM strength, running speed 0-10 and 0-30 m and jump height within squat jump, drop jump and countermovement jump (Tsimahidis, Galazoulas, Skoufas & Papaiakovou 2010, pg. 2103-2104; Ross, Ratamess, Hoffman, Faigenbaum, Jie & Chilakos 2009, pg. 390). Testing high within the aforementioned criteria is a way to assess the demands of the sport on the athlete as well as the capacity of the individual. With as little as 8 weeks of periodized strength training gains were seen within athletes of maximum strength (19 %) explosive strength (6-10 %) as well as 0-10 m sprint time by 6 % (Moir, Sanders, Button & Glaister 2007, pg. 291-295). This leads to the logical conclusion that strength training should be a predominant part of any athletes training routine.

Great gains have been shown in anaerobic endurance when high-intensity sprint training has been introduced into regular training programs. Basketball is played at a very intense level using the energy substrates of anaerobic creatine phosphate and the anaerobic glycolytic system (Bompa 2009, pg. 122). This being the case the ability to tolerate lactic acid, which is a byproduct of anaerobic glycolysis energy system would be an advantage since this prevents contractions and thus lessens physical movements. Supplementation of short duration sprints with regular training seems like a positive choice in that you have the lactic acid production aspect which the body becomes acquainted too, as well as the repeated tolerance ability which pertains to the body's ability to tolerate and work at higher levels of lactate acid concentration (Walklate, O'brien, Paton & Young 2009, pg. 1480). This leads to the conclusion that regular training with sessions of short duration sprint training leads to increases in repeated-sprint performance and agility as well as the ability to endure the lactic acid by product of high intensity sprints which is a necessity in basketball.

When one thinks of Basketball not only does one see great speed and jumping ability but also an amazing amount of agility. Agility pertains to the efficiency of physical movement or rather the ability to instantly change direction. Agility has been noted and examined by scientist, the results garnered were that agility, sprinting speed and jumping ability are all interlinked and should be combined together in order to enhance performance development of athletes (Sporis, Milanovic, Jukic, Ormcen & Molineuvo 2010, pg. 70).

In closing sprint training affects muscle and physical performance (Tsimahidis et al. 2010, pg. 2103-2104; Ross et al. 2009, pg. 390). Thus with this in mind what conclusions would scientists garner from sprint training over short distances for 6 weeks. What was noted by sports scientists was that sprint training increased the proportion of type II muscle fibers as well as improving endurance and sprint ability (Dawson, Fitzsimmons, Green, Goodman, Carey & Cole 1998, pg. 164-166). So from this conclusion, one could reason that the aforementioned training would compliment a basketball player if speed, jumping height and agility is important to their game.

Strength

Investigations into strength (resistance) training and its relationship to sports has revealed a link which suggests that the physically stronger the athlete is, the better equipped they will be to handle the stresses of injury, training and competition (Bompa 2009, pg. 122). Simply put strength is the maximum amount of force a muscle can generate through a contraction. There are several variables which must be taken in to account when applying a strength training plan, Squat 1RM which pertains to having knowledge of the most amount of weight the subject can lift once and thereby dividing this weight into different percentages so as to progressively train heavier in order to become stronger (Progressions principle). Intensity pertaining to weight, frequency of how often one trains per week and volume of how much is to be trained in each session (Thomee, Augustsson, Wernborn, Augustsson & Karlsson 2008, pgg. 74). A literature review has revealed that on average to improve strength, 5-6 reps at 85% of 1RM in squat exercise will yield optimal strength gains for those with a concurrent history of training i.e. more than a year (Hoffman & Kang 2003, pg. 112-113; Ratamess, Alvar, Evetoch, Housh, Kibler & Kreamer 2009, pg. 687-689). Lately it has been revealed that with beginners to strength training a percent of 60-70% of 1RM will give optimum strength gains (Rhea, Burkett & Ball 2003, p. 457-458). Due to prolonged resistance training, adaptations mainly occur in the neuromuscular system (Fleck & Kraemer 1997, pg.). The neuromuscular system pertains to the motor system/unit which is controlled by a motor neuron that transmits impulses which can halt or excite response by muscle fibers innervated by that motor neuron. (Wilmore, Costill & Kenney 2008, pg. 86). Two of the most important strength training principles are that of overload which means that to improve the muscles strength/power the training load must put a sufficient stress on the neuromuscular system so as to surpass the load it is accustomed to lifting and that of specificity which implies that to become better at a particular exercise or skill, you must perform that exercise or skill (Beachle & Earl 2008, pg. 379-380).

There are many different forms of strength training (speed strength, strength endurance, power, and max strength etc.) and systems (linear/undulating periodization, supersets, drop-sets etc) to enhance performance characteristics within muscles (Fleck & Kraemer 1997, pg. 7-47, 117-130). But which one is the more suitable when specificity of movement is required. With this in mind two popular forms of strength training Olympic lifts (OL) and the other Power Lifting (PL) were compared to evaluate which one would reap the most benefits for athletes in the tested parameters, the results leaned toward OL since low force high velocity strength training was found to elicit more power gains (Hoffman, Cooper, Wendell & Kang 2004, pg. 132-133). Although both training interventions saw gains with implementation of the popular squat movement as a lower body strength exercise.

A rest time of 3-5 min between sets has also been shown to be adequate recuperation time to refuel the creatine phosphate (CP) system which is needed when the goal of the training is max strength (Mirzaei & Saberi 2008, pg. 223-224; Miranda, Fleck, Simao, Barreto & Dantas 2007, pg. 1033-1044).

In the NBA, the league considered to be the most competitive in the world, all strength and conditioning coaches make use of periodized weight training programs when training their athletes. In these programs all coaches employed plyometric and squat variations, as well as the Olympic-style lifts and their derivatives (Simenz, Dugan & Ebben 2005, pg. 496-502).

Plyometrics

Plyometrics is the name given to the stretch shortening cycle (SSC). This type of training has been around for a number of years; many scientists have written and analyzed its potential as a way to improve force/power within groups of muscle. The premise of SSC is that when a muscle is loaded (eccentric-lengthening) just before a (concentric shortening) it will produce a greater force due to the stored elastic energy. This requires that the amortization phase be very short (the time between the eccentric and the concentric contractions) so as to take advantage of the stored elastic energy before it dissipates. The faster the eccentric phase is performed the more explosive the corresponding movement (Fleck & Kraemer 1997, pg. 35-38 ; Chu 1998, pg. 5; Beachle & Earl 2008, pg. 414). Plyometrics exercises are used to promote power (speed strength) within a muscle; they are explosive in nature and are trained mainly through the use of hopping, bounding and or jumping within the lower extremities in order to improve the neuromuscular system for the purpose of movement (speed/agility) within a sport. The ability to apply force (Reactive Force) is the major goal of Plyometrics (Chu 1998, pg. 4). The two main components agreed upon by scientist as to how the SSC works are A; the elastic components of muscle tendons, referred to as the elastic band effect (when stretched there exists elastic potential to return to its normal length). The B; component relates to the sensors in muscle spindles (muscle proprioceptors) which sense length and velocity of muscle contraction thus changes in the rate of action potentials (release of calcium ions which free up tropomyosin which aids in muscle contraction) intensifying the stretch reflex (ibid, pg. 3). One can say this is a prohibitive measure by sensory organs so as to avoid injury to the muscles by limiting the amount of the muscle sarcomeres length and the velocity of contraction.

What needs to be answered is the amount of plyometric training that can be undertaken in a session, and or over a week. To answer this question a met-analysis study was conducted to assess variables of plyometric training with a view to improving vertical jump height performance. The scientists came to the conclusion that 10 weeks using high-intensity programs (50 jumps per session)combined with intense plyometrics i.e. countermovement jump (CMJ), squat and depth jump (DJ) is recommended rather than using a single training form (Saez-Saez de Villareal, Kellis, Kraemer & Izquierdo 2009, pg. 500-502). How can greater improvement in performance be maximized in agility, jumping height and speed? The answer lies in improving hip and thigh power production, which is an important factor in improving vertical jump height and sprinting, usually enhanced by squat training. The stronger these muscle groups are the more power one can elicit with correct training methods. Thus a combination of squat and plyometric together should significantly elicit greater jump height. As was the case when an intervention of this type of training was completed over several weeks (6-12) resulting in improved motor performance (ability of the neuromuscular system to perform specific tasks) in the intervention group within the study (Adams, O'Shea, K O'Shea & Climstein 1992, pg. 39). Also the introduction of weight implements when combined with jump squats has been seen to improve power production and agility within athletic men (Mcbride, Triplett Mcbride, Davie & Newton 2002, pg. 79).

Frequency of plyometric training pertains in this case to the amount of times per week one trains these exercises, because quality is always better than quantity. For this reason forty-two students were divided and placed within 1, 2 or 4 days per week training. The underlying results were that similar gains were made within the 2 and 4 day groups, but the 2 days a week group had better efficiency within their jumps (Saez-Saez de Villareal, Gonzalez-Badillo & Izquierdo 2008, pg. 719-722). This study highlights that the 2 day per week training cycle is more proficient for power training and is less fatigue inducing than higher training loads.

As a trainer/coach, efficiency with training or rather time management is important! So as to resolve a dilemma of time restraints, which type of plyometric exercise elicits the most superior gains (most bang for buck) between countermovement Jump (CMJ) or Depth Jump (DJ). The answer from a study conducted on these two plyometric jumps, was that the depth jump is the superior of the two due to its neuromuscular specificity (Gehri, Ricard, Kleinerl &

Kirkendall 1998, pg. 86-88). This in combination with lateral plyometrics can enhance power production and quickness when implemented in a program for basketball players (King & Cipriani 2010, pg. 2112-2114). The main emphasis of plytometric training is reduction in sprint time and an increase in jumping ability (Radcliffe & Farentinos 1999, pg. 1-10).

Post activation Potential

Post activation potential (PAP) is the name given when acute muscle force output is increased as a result of previous contractile exercise. It has been postulated that explosive movements may be enhanced if preceded by a heavy resistance exercise (Robbins & Docherty 2005, pg. 900-901; Robbins 2005, pg. 455-456). There are two explanations pertaining to the existence of PAP. The first involves an increased phosphorylation in the sarcomere (basic unit of a muscles cross striated myofibril), making muscle contraction more powerful leading to enhanced force production of the muscles trained (Docherty, Robbins & Hodgson 2004, pg. 53; Hamada, Sale & MacDougall 2000, pg. 407). The second explanation refers to the H-reflex (Spinal Reflex) which due to PAP enhances the ability of afferent muscle nerves to send impulses to muscles more proficiently (Hodgson, Docherty & Robbins 2005, pg. 587-589). An example would be if an athlete squats with an external load equivalent to 85% 1RM and higher so as to recruit all motor units and the corresponding muscle fibers it innervates, this percentage of 1RM is according to previous research been shown to induce potentiation of the nervous system whereas sub maximal contractions of less than 85% do not (Gullich, Schmidtbleicher 1991, pg. 67-81). This is then followed by an explosive movement such as a squat jump which could potentially increase the athletes muscle power output, because the nervous system is stimulated giving a heightened neural response in the movement patterns trained.

Many short term studies have been conducted on the power enhancing properties of PAP (Chatzopoulos, Michailidis, Giannakos, Alexiou, Patikas, Antonopoulos & Kotzamanidis 2007, pg. 1278; French, Kraemer & Cooke 2003, pg. 681-682; Young, Jenner & Griffiths 1998, pg. 82-84). The results from these studies have revealed that when pre and post test scores have been compared, participants in the studies improved acute scores in all subsequent tests, acceleration 0-10 and 0-30 m, jump height and maximal force.

To utilize the benefits of PAP on athletes, the rest time between the potentiating exercise and the athletic movement to be performed must be considered. Most studies have cited rest times of up to 5 minutes length between paired exercises, so as to take advantage of the positive effects of PAP (Chu 1996, pg. 143-144).

Complex Training

Complex training is at its base is a power-developing training protocol that combines strength training (weights) and plyometric exercises completed in tandem. Its genesis originated out of the idea of the PAP principle. An example would be to complete a set of six squats followed by a set of six jump squats (Chu 1998, pg . 65-66). The premise of complex training is that the muscle power output is enhanced after a maximal or near maximal contractions from strength training (Verkoshansky 1995, pg. 7). Also slow twitch fibers have been known to behave like fast twitch fibers due to the activation of the neuromuscular system (Chu 1996, pg. 10). This not only is ideal for time purposes but also an ideal way to improve jump characteristics in vertical jump height by as much as 5 % in four weeks (Mihalik, Libby, Battaglini & McMurray 2008, pg. 50-51). This makes it ideal as an in-season training program to enhance muscle power output.

Even with as little as two weekly training sessions over a period of ten weeks complex training can enhance performance in adolescent basketball players by improving the muscle power output (Santos & Janeira 2008, pg. 906-907). Muscle power output refers to the amount of force a tested muscle or muscle group can generate (Demura & Yamaji 2006, pg. 137-138).

Aim and Questions

This study aims to evaluate the physiological effect of two weekly in-season training sessions consisting of a combination of squats, plyometrics, sprint training and repeated shuttle sprints over a period of six weeks upon Swedish division 2 basketball players. To reach the aim of the study the following question was used

- What is the effect of an intervention of six weeks of combined training on the physical characteristics of Swedish young basketball players?

Our hypothesis is that a supervised in-season complex training program based on squats, plyometric exercises, acceleration and repeated sprints will enhance basketball player's physiological capacity more than non periodized strength training.

Method

Literature Study

A thorough literature review was conducted on scientific articles found through searches on various sports science data bases (attachment 1). The aforementioned searches produced other relevant literature through their references.

Subjects

To reach the aim of this study we decided to make a training intervention on a basketball team consisting of young male basketball players with preferably little to no previous experience in strength training. In order to compare the results of the training intervention to regular basketball training, we located another basketball team with similar characteristics to the intervention group (IG) so as to serve as a control group (CG).
Inclusion criteria were:

- Completion of pre and post-tests
- Training participation requirements of 83 %
- Absence due to illness and injuries during the training study

Intervention group (IG)

A convenience sample consisting of young adults was chosen to serve as the IG. The members of the team had little to no previous experience of periodized strength training and would be classed as inexperienced lifters (Hurst, Hale, Smith & Collins 2000, pg. 433). At commencement eighteen players took part in the study. Due to the inclusion criteria seven players were included in this study. The age and anthropometrical measures of the subjects are presented in table 1. The IG's in-season training consisted of four 90 minutes basketball training sessions and one game per week during the six week intervention.

Tabel 1. Anthropometric data and age of IG and CG reported as mean ± SD.

	IG n=7	CG n=6
Age (yrs)	18,4 ± 1,1	18,3 ± 2,3
Weight (kg)	75,9 ± 11,3	88,9 ± 11,7
Height (cm)	178,9 ± 12,6	190,8 ± 5,6

Control group (CG)

The CG was made up of twelve players; because of the inclusion criteria six players of similar age and from the same division as the IG were included in the study as a CG. The CG were all labelled as inexperienced lifters (Hurst, Hale, Smith & Collins 2000, pg. 433). Anthropometrical data and age are noted in table 1.

The CG had four 90 minute basketball training session and one game weekly. The team had a functional strength training program consisting of body weight, rubber band and stability ball training that was carried out twice weekly individually.

All participants were given a detailed explanation of the aim of the study and a description of what tests would be used and how the training intervention would be conducted before the commencement of the study. Furthermore the participants were informed that they at any time could withdraw from the study or test without any explanation. A written consent was signed by all participants of age (18yrs). Those participants that were under aged sought parental consent. (Attachment 2)

Training Intervention

Twelve training sessions were conducted over a period of six weeks (twice weekly) set apart by 48 hours. The intervention was divided into two periods of three weeks, with the first period concentrating on sprinting, agility and strength, and the second period focused primarily on strength and plyometrics. The order of training intervention was based upon the intervention group being able to meet the adequate strength requirements necessary to be able to tolerate plyometric training. The total training time was divided up and is presented in figure 1.

Each session was approximately 60 min in length, making the entire training time of the intervention 720 min. These sessions were followed by 30 minutes of basketball technique training conducted by the teams coach, as well as two 90 minute basketball sessions and one game per week. All intervention sessions were supervised by one to two certified strength training instructors who where well acquainted with instruction and technique of the strength training components.

Training sessions were conducted on Tuesdays and Thursdays between a wooden floored sports hall and a rubber floored sports hall with an adjoining weight training room. The intervention groups coach adjusted the content of the team's usual training to facilitate the study with adequate rest times between the training days.

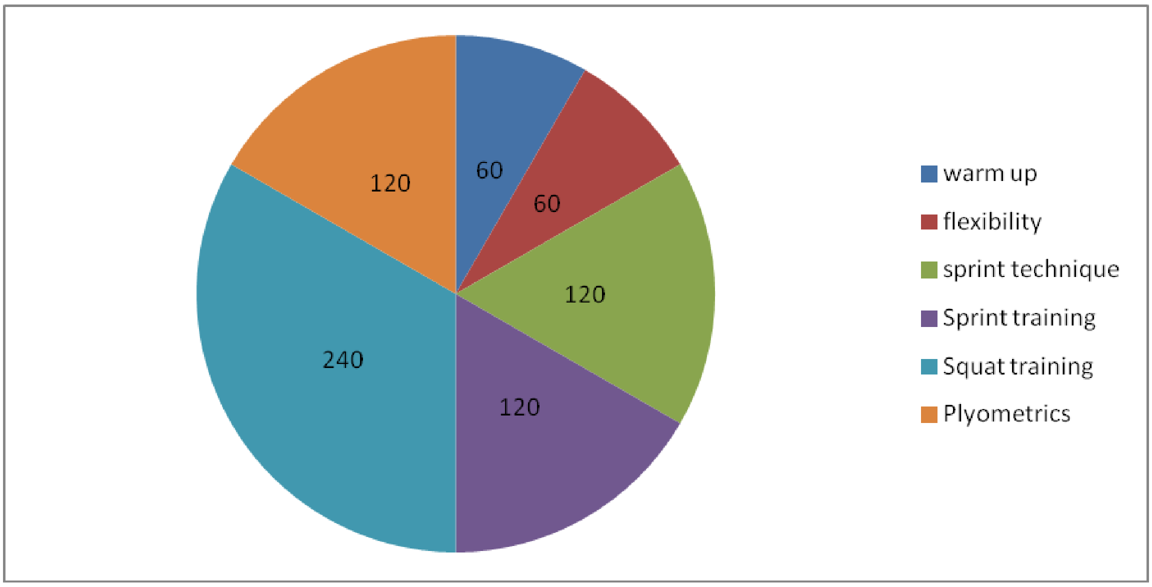


Figure 1. Division of training throughout the intervention described in minutes.

All training session commenced with a 20 minute standardised routine consisting of five minutes of low intensity jogging, followed by five minutes of flexibility exercises, there after 10 minutes of sprint technique drills were conducted. The primary strength training component (half squat) was used throughout both training blocks. Its execution was to be done as explosively as possible in the concentric phase followed by a 2-3 second controlled eccentric movement. Throughout the intervention the warm-up routine was followed by agility on Tuesdays and repeat sprint shuttle ability (RSSA) on Thursdays. During the first period (weeks 1-3) the warm-up routine was followed by sprint exercises and finished with the half squat. In the second period (weeks 4-6) the warm-up routine was followed by half squats and plyometrics (Table 2).

Table 2. Training program of the intervention group.

Warm-up						
Jog	5 min					
Flexibility program	5 min					
Sprint technique	10 min					
Sprints	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**
Marching A drill	2 x 20m	2 x 20m	2 x 20m			
Skipping A drill	2 x 20m	2 x 20m	2 x 20m			
Running A drill	2 x 20m	2 x 20m	2 x 20m			
Resisted sprint	2 x 20m	2 x 20m	2 x 20m			
T-test*	6 x/60s	6 x/60s	6 x/60s	6 x/60s	6 x/60s	6 x/60s
40 m shuttle sprint	7 x 40/20s	7 x/20s	7 x/20s	7 x/20s	7 x/20s	7 x/20s
Squat program	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**
	4 x 10/3min	4 x 8/3min	4 x 6/3min	5 x 10/3min	5 x 8/3min	5 x 6/3min
Plyometrics	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**
Stiffnessjumps				2 x 6	2 x 6	2 x 6
Jump squats				2 x 6	2 x 6	2 x 6
Hurdeljumps				2 x 6(50cm)	2 x 6(50cm)	2 x 6(60cm)
DJ				2 x 6(30cm)	2 x 6(30)*	2 x 6(30)**

Sets x reps/rest time(height)
*DJ followed by a 5 m sprint
**DJ followed by a 90 degree change of direction to a 5 m sprint

Test methodology

As a means to evaluate the effect of the intervention, pre-tests were conducted before the start of the intervention and a post-test upon the completion of the six week training intervention within 48-96 hours.

A test battery was designed to evaluate the physiological outcome of the intervention through a pre and post training comparison.
The physiological demands set on the sport which we wished to evaluate were as follows:

- Jumping ability i.e. muscle power output (SJ, CMJ_a, 5JT and JS)
- Reactive force (ODJ)
- Ability of directional change i.e. Agility (T-test)
- Ability to maintain maximum speed repeatedly i.e. Speed endurance (RSSA)
- Ability to maintain speed throughout match i.e. Specific endurance (YY IR1)

The squat jump (SJ), Counter Movement Jump free arms swing (CMJ_a) and the five horizontal jumps for distance (5JT) for lower body explosive strength. (Markovic, Dizdar, Jukic & Cardinale 2004, pg, 551-555; Chamari, Chaoucha, Hambli, Kaouech, Wislöff & Castagna 2008, pg. 944–950). Muscle power output was assessed through the jump squat test (JS) (Cormie, McBride & McCaulley 2007, pg. 103-118).

The optimal drop jump (ODJ) for reactive force (Bobbert, 1990; Byrne, Moran, Rankin, & Kinsella, 2010).

The T-test is designed to test agility (Pauole, Madole, Garhammer, Lacourse & Rozenek 2000, pg. 443-450; Munro & Herrington 2010, pg. 944–950) and repeated sprint shuttle ability (RSSA) for accelerative speed and for speed endurance (Impellizzeri et al. 2008, pg. 899-905)

Yo-Yo intermittent recovery test level one (YY IR1) was validated to measure specific endurance in intermittent team sport such as football and basketball (Castagna, Manzi, D'Ottavio, Annino, Padua, & Bishop, 2007, pg. 202-208).

Two to three test leaders were responsible for the data collection during the pre and post tests. Both pre and post tests were carried out on two consecutive days after 24-48h of inactivity. All tests when conducted were verbally encouraged by the test leaders. The tests were carried out in the order described in figure 2.

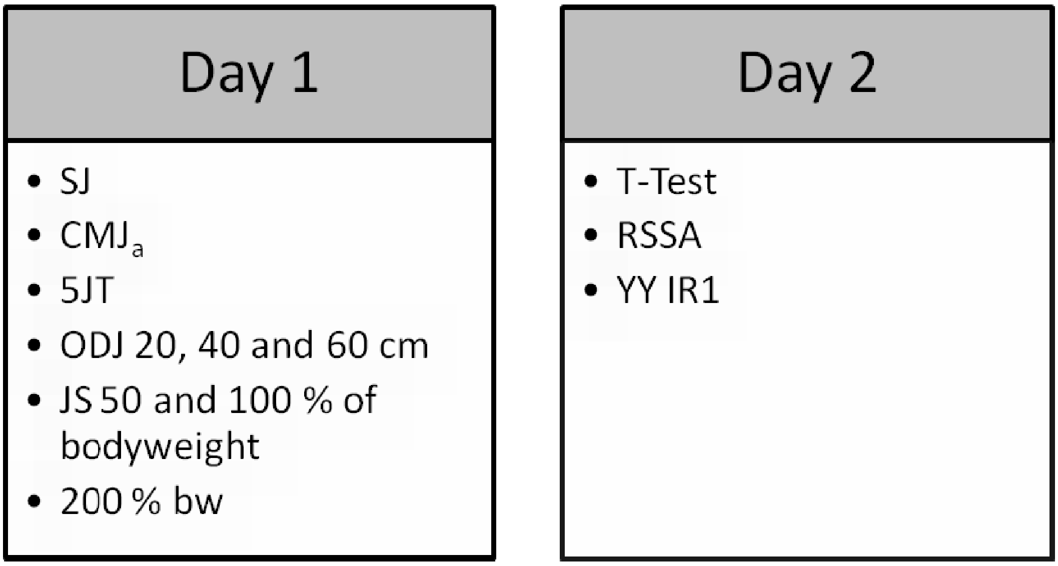


Figure 2. Test order.

Apparatus and Test Setup

The SJ, CMJ_a and ODJ tests were all conducted on a rubber indoor floor within the confines of the LTIV laboratory (GIH) and the results measured with an OptoJump “light mat” using the Optojump Next v. 1.3.9.0 software to calculate the jump height and floor contact time by measuring .

In the 5JT a tape measure was used to measure the length from the front of the feet at the starting point, to the heel of the foot upon completion of the jump.

In the JS test concentric squats jumps and the 200 % bw lifts from 90° knee angle were performed with a barbell suspended in a Smith-machine (Cybex). During the lifts, security locks were placed on the smith machine at a pre-measured knee position of 90° to prevent the concentric squat being performed at less than 90°. A vertical displacement linear encoder (Muscle Lab., Ergotest Technology AS, Norway) was used to enable calculation of power output in each lift. A body mass fraction of 90 % was included in the power calculation.

The sprint and agility tests (T-test, RSSA and YY IR1) were all executed on wooden floor full size gymnastic halls. The times for the T-tests was measured with a Cielo WC-061 stopwatch. The results for the RSSA were measured with photocell gates (IVAR Measuring systems, Estland). Each photocell contained two measuring cells which both had to be interrupted simultaneously to trigger the time device. An mp3 player connected to a portable speaker was used during the YYIR1, the distance covered in meters in the YY IR1 was noted on a prepared sheet.

Procedure

Squat jump (SJ)

In the SJ test the subject started from an upright standing position. The subject was instructed to start squat down until the test leader approximated a knee joint angle of 90 ° and called out a verbal command to stop. Subject could then extend the legs at free will as explosively as possible reaching as high as they physically could. The hands grasped the hips for the length of the entire test with thumbs pointing backwards. The subjects were instructed to finish the SJ by performing a couple of stiffness jumps immediately after landing to ensure that the toes were landing first. The subject was not allowed to employ a preliminary downward phase (i.e., a countermovement or hip/back flex-extension) to avoid the pre-stretching of the legs.

Counter movement jump free arm swing (CMJa)

The CMJ_a test consists of performing a single jump with a maximal effort from a standing erect position i.e. straight legged. The subject is free to use an arm swing in the upward movement of the jump. The jump height (cm) was measured during the dynamic movement.

Optimal drop jump (ODJ)

The optimal DJ test consists of stepping of a raised platform from different heights (i.e. 20, 40, 60 cm) and upon landing, immediately performing a vertical jump. Two boxes, one 20 cm in height and the other 40 cm were used to create the different drop heights used in the ODJ test. To create the 60cm box the 20cm box was stacked upon the 40cm.The subject was instructed to drop from the box and jump as high and with as little contact time on the ground as possible. Two jumps were recorded on each height due to safety concerns and training experiences of subjects. The jumps were performed in the order of 20, 40 and 60 cm with a 15 second rest between each jump and a two minute rest between changes of box height. The ODJ ratio was calculated by dividing the jump height by the ground contact time and the best result for each height was selected for analysis.

5 jump test (5JT)

The subject started with both feet parallel behind a fixed position and is prohibited from performing a back step. The test starts with a forward jump landing upon leg of choice and continues with alternating jumps for distance between left and right foot for a total of four jumps, finishing the jump series by landing with parallel feet on the fifth step. If the subject falls backwards on completion of the last jump, the attempt is void and must be performed again. An assessment of the landing distance is made visually by the test leaders. Three successful attempts were recorded.

Jump Squat (JS)

In the JS test, the subjects lifted an external load equal to that of 50 % and 100 % of their body weight in the smith machine. The subjects were instructed to perform an explosive concentric movement (jump) from the start position of 90° knee angle. The power was calculated during the concentric phase. The subject continued new attempts with a 15 second rest between jumps until there was a drop in force production with the new attempt. Between changes of load the subjects were given 3-5 min rest, so as to ensure maximal recuperation.

200 % of bodyweight (200 % bw)

The 200 % bw lift was performed in the smith machine. The subject was instructed to lift the weight as forcefully as possible from the same start position as in the JS but without the jump. The power was calculated during the concentric phase of the lift and the best trial of two was selected and recorded due to the inexperience of the subjects. Between lifts the subject was given a 3-5 min rest, so as to ensure maximal recuperation.

T-test

The subject started at the start/finish line and sprints 9 meters forward to touch the B-cone with optional hand, followed by a side shuffle of 4,5 meters to the left to touch the A-cone with the left hand. This is followed by a 9 meter side shuffle to the right were the subject

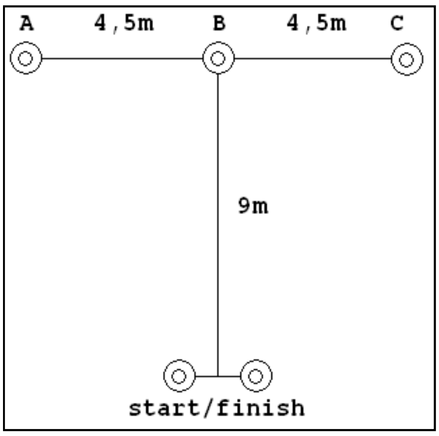


Figure 3.Configuration of T-test.

touches the C-cone with the right hand then side shuffles back 4,5 meters to the B-cone to touch it with hand of choice. This is followed by a 9 meter back-pedal (backwards running) to the start/finish line (Figure 2). If participants failed to touch a cone or side stepped over their own feet the test would be deemed void.

Repeated shuttle sprint ability

The subject sprinted 20 meters straight forward to touch a line with the foot, and then completes a 180°change of direction to sprint back towards the start line as fast as possible. After completing a shuttle, 20 seconds of passive recovery is given, before the start of the next shuttle. Six shuttles were completed in entirety.

Yo-Yo intermittent recovery test level 1

In the YY IR1 the subjects started behind the start line. On an auditive cue the subjects ran towards the turning point set 20 m away. A 180° turn was made after stepping on the turning point line to return to the start point. The auditive cue marked the commencement of each 20 m sprint. A period of 10 seconds active rest between each 20 + 20 m shuttle was given, whereby the subject jogged or walked around a cone set 5 m from the starting line. The speed of the shuttles increases progressively until the subjects were unable to complete a shuttle (cover distance) within two consecutive timed trials (Figure 3). The distance covered in the YY IR1 can be used to roughly estimate VO_{2max} values using the following equation:

VO_{2max} (mL/min/kg) = YY IR1 distance (m) x 0,0084 + 36,4 (Bangsbo, Iaia & Krustrup 2008, pg. 47)

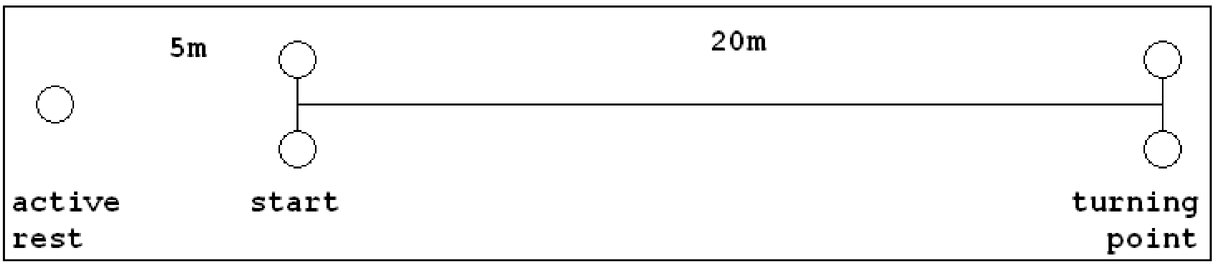


Figure 4. Configuration of the Yo-Yo intermittent recovery test level 1.

The best result of each test protocol was selected for analysis.

Statistical Analysis

All values are reported as mean ± standard deviation (SD). A 2-tailed paired sample t-test was used to test for significant changes within groups between pre and post training. An ANOVA repeated measures model was used, to evaluate the pre and post differences between groups. Pearson’s correlation coefficient was used to investigate the relationships between the different tests with both IG and CG results pooled. Correlations were set to: trivial 0.0–0.1, low 0.1–0.3, moderate 0.3–0.5, high 0.5–0.7, very high 0.7–0.9, and practically perfect 0.9–1.0 (Hopkins 2011-01-27).

Validity and Reliability

All tests methodology were validated and checked for reliability in the studies mentioned before. We feel these studies have given validity to the test battery used in the study as the tests have been conducted upon numerous documented subjects and also have been published in peer reviewed journals (Bobbert 1990, pg.7-22; Pauole et al. 2000, pg. 443-450;Markovic et al. 2004, pg, 551-555; Castagna et al. 2007, pg. 202-208; Cormie, McBride & McCaulley 2007, pg. 103-118; Chamari et al. 2008, pg. 944–950; Impellizzeri et al. 2008, pg. 899-905; Byrne et al. 2010, pg. 2050-2055; Munro & Herrington 2010, pg. 944–950). Peer reviewed articles are considered to be a certification of validity in the scientific community as these articles have gone through stringent impartial evaluations by experts in that specific field.

The equipment at LTIV is regularly calibrated by the technicians so as to give accurate measurement in all tested parameters. To ensure this accuracy, validity and reliability tests were conducted on the equipment by the intervention authors.

As the average power production in the concentric part of the JS is calculated by using the velocity and the displacement of the mass being moved, a validity test was carried out on the displacement of the mass. The validity of the barbell displacement was tested by moving the barbell ten times over a premeasured distance of 31.5 cm on two different occasions separated by 48 hrs and correlating this to the output information given by the muscle lab program of the computer. The mean and standard deviation results from the Musclelab program was 31.53cm ± 0.08 cm making the correlation very high (R = 0.999) validating this parameter.

Test retest comparison of the Optojump output verified a strong correlation between test retest results (R = 0.856).

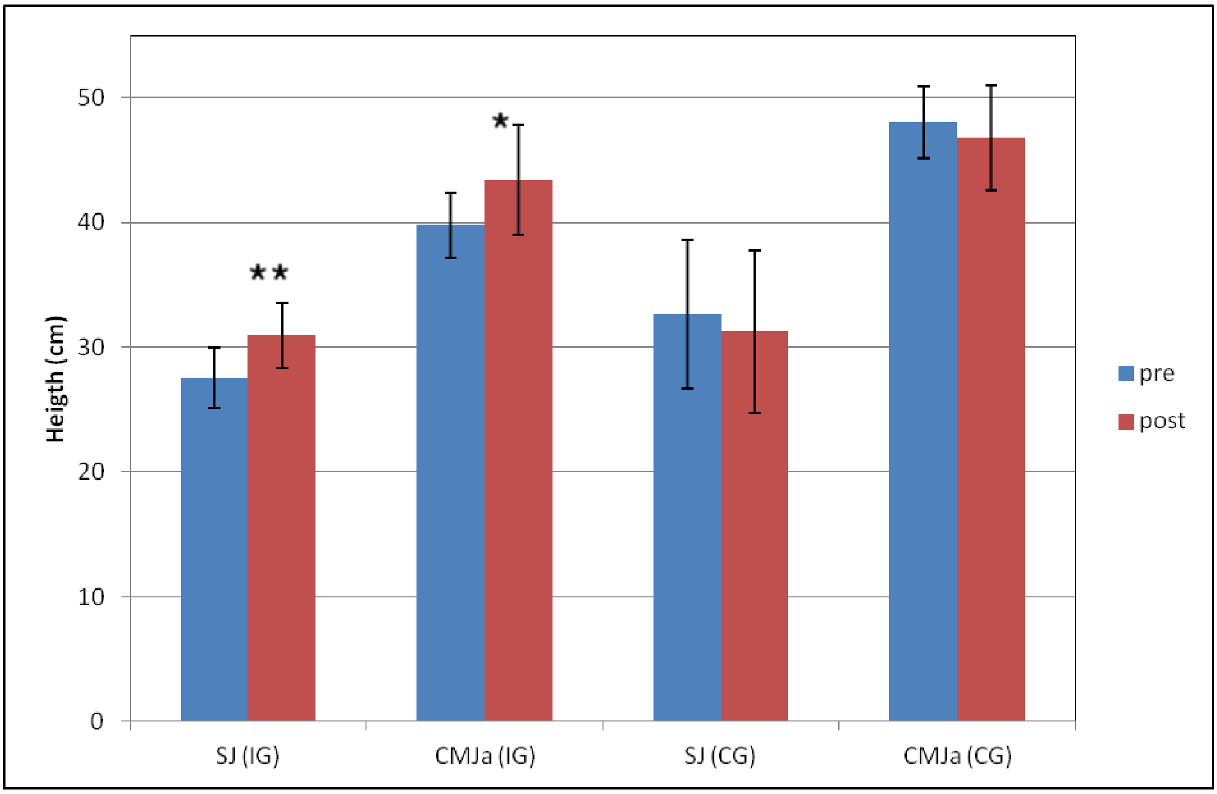
Three healthy male GIH students (aged 34 ± 7 years, weight 87 ± 6 kg, height 182 ± 8 cm) were enlisted to aid in test-retest reliability of the Optojump instrument responsible for information processing in the SJ, and CMJa. Test retest was conducted with a 48hr window between test days. The results attained showed great correlation (R=0,993) confirming previous research (Munro & Herrington 2010, pg. 944–950). The tests of the intervention were also filmed so as to assess validity of the jump by analyzing correct execution of movement.

The accuracy of the IVAR photocell system was tested for standard error of measurement by interrupting two photocell light beams at 10 cm intervals. The total distance between photocells and reflector was 150 cm as in the test. The results showed a 0.7 cm amplification at the beams widest distance which was at 75 cm. As the total distance of each shuttle run within the RSSA is 40 meters the slight disturbance is negligible since the standard error of measurement is low (0.02%).

To ensure that the effects of the intervention results were valid we chose to set the acceptable nonattendance for the intervention at a high level of two absences from training sessions of 12 (83 %). The test procedures were standardized with the supervision of experienced test leaders from the Swedish Sports Development Centre at Bosön and LTIV at The Swedish School of Sport and Health Sciences.

Results

There were no differences between groups in total training volume during the intervention period, although there were differences in the amount of heavy strength training between the IG and CG favoring the IG.



**. Changes are significant at the 0.01 level (2-tailed).

*. Changes are significant at the 0.05 level (2-tailed).

Figure 5. Pre and post results of the SJ and CMJa for both groups.

The IG SJ pre test value were 27,5 ± 2,4 cm and significantly increased (p<0,01) to 30,9 ± 2,6. In the CMJ_a the pre to post results significantly changes (p<0,05) from 39,8 ± 2,6 cm to 43,4 ± 4,4 cm. The CG's SJ and CMJ_a scores decreased by 1,4 cm and 1,2 cm respectively although these changes failed to show statistical significance (figure 5).

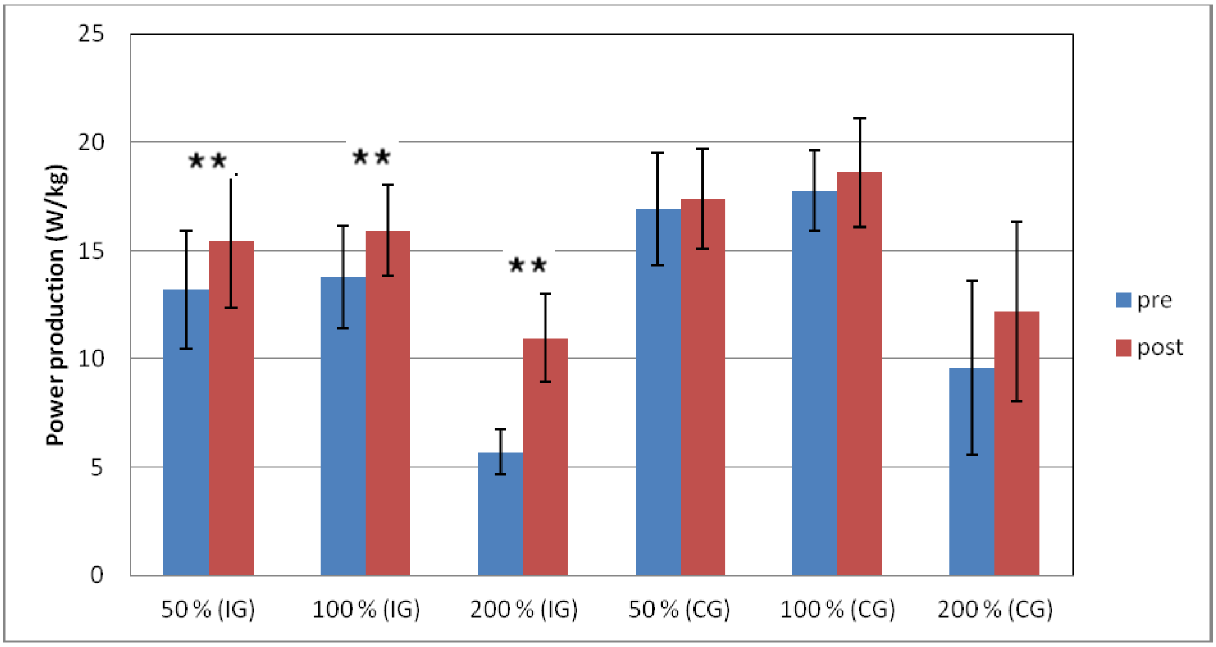
For the IG the jump height and contact time increased from all drop heights. The CG lowered the contact time and jump height from all three platforms. Only the ODJ 20 cm height of the IG showed significant changes of all other measured parameters of the ODJ. The complete results for the ODJ are presented in table 3.

Table 3. Mean ODJ results and pre-post changes for both groups.

	Intervention group				Control group			
	Pre	Post	Change	Change %	Pre	Post	Change	Change %
DJ 20 t(s)	0,246	0,270	0,024	9,8%	0,245	0,226	-0,019	-8,2%
DJ 20 (cm)	33,5	36,6	3,1	9,4%	43,7	39,9	-3,8	-9,5%
DJ 20 ratio	144,1	139,5	-4,5	-3,1%	180,8	180,2	-0,6	-0,3%
DJ 40 t(s)	0,239	0,249	0,009	3,9%	0,239	0,221	-0,018	-8,2%
DJ 40 (cm)	33,9	36,9	3,0	8,8%	41,5	38,5	-3,1	-7,9%
DJ 40 ratio	144,6	152,6	8,0	5,5%	176,5	178,9	2,4	1,3%
DJ 60 t(s)	0,240	0,249	0,009	3,8%	0,252	0,231	-0,020	-8,7%
DJ 60 (cm)	34,1	34,3	0,3	0,8%	41,4	38,8	-2,6	-6,8%
DJ 60 ratio	143,3	139,2	-4,1	-2,9%	169,3	171,8	2,4	1,4%

There were tendencies of gains in the 5JT performed by the IG where the mean distance increased by 0,66 m from 11,26 ± 1,24 m to 11,92 ± 0,74. The CG 5JT scores were lowered by 0,25 m. Both groups 5JT results failed to show any statistical significance.

In both groups there was a substantial increase in all measured variations of the JS (figure 6). The IGs changes were all significant (p<0,01) while the CG changes showed no significance. At JS 50 % bw for the IG there was an increase of muscle power output from 13,2 ± 2,7 W/kg to 15,5 ± 3,1 W/kg. The change for JS 100 % bw were 13,8 ± 2,4 W/kg to 15,9 ± 2,1 and 5,7 ± 1,0 W/kg to 11,0 ± 2,0 W/kg for the JS 200 % bw.



**. Changes are significant at the 0.01 level (2-tailed).

Figure 6.Power production changes for both groups in JS and the 200 % lift.

The results of the agility T-test showed lowered times for both groups although only the IG changes showed significance (*p*< 0,01). The time in the IG was reduced from 9,56 ± 0,36 s to 8,93 ± 0,12 s thus leading to a change in mean by -0,63 s while the CGs time was lowered by 0,28 s.

In the RSSA the maximum time of a shuttle was the only significant value of change (*p*<0,05) for the IG and lowered by 0,189 s. The minimum shuttle time increased by 0,037 s and the fatigue index declined to 2,7 %. The CG RSSA results showed a insignificant marginal increase in time of the shuttles and the fatigue index (table 4).

Table 4. Mean RSSA results and pre-post changes for both groups.

	Intervention group				Control group			
	pre	post	change	change %	pre	post	change	change %
RRSA min (s)	7,27	7,31	0,04	0,5%	7,02	7,04	0,02	0,3%
RSSA max (s)	7,86	7,68	-0,19*	-2,4%*	7,47	7,51	0,04	0,5%
RRSA Fi (%)	4,54	2,71	-1,83	-40,2%	3,82	3,91	0,09	2,3%

*. Changes are significant at the 0.05 level (2-tailed).

The IG increased the distance covered significantly (*p*<0,01) in the YY IR1 by 463 m, from 1411 to 1874 m in distance covered. Scores of the CG were lowered by 33 m from 1920 to 1887 m. The estimated VO_{2max} values from the YY IR1 test results, increased with 3,9 mL/kg/min in the IG and decreased 0,3 mL/kg/min in the CG.

There were significant correlations (*p*<0,05) between relative strength in the 200 % bw (W/kg), vertical and horizontal jump performances, the agility T-test, RSSA and the YY IR1. The 5JT correlated with all tests except for the ODJ, while the agility T-test showed high correlations with all tests but the ODJ and JS 50 % bw (table 5).

Table 5. Correlation table of the 200 % bw, T-test and 5JT.

	SJ(cm)	CMJa(cm)	JSR 50 % bw	JS 100 % bw	R 200 % bw	T-test (s)	RRSA min (s)	RSSA max (s)	5JT (m)	YY IR1 (m)
200 % bw	0,570**	,555**	,654**	,766**	1	-,674**	-0,373	-,676**	,497*	,627**
T-test (s)	-,502**	-,490*	-0,295	-,427*	-,674**	1	,551**	,467*	-,507**	-,563**
5JT (m)	,651**	,728**	,434*	,574**	,497*	-,507**	-,457*	-,732**	1	,692**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The repeated measures ANOVA showed significant in-between groups differences in the pre test CMJ_a, DJ20 h, DJ40 h, all JS and the $RSSA_{max}$. In the post test comparisons the $RSSA_{min}$ was the only test to show significant differences.

Discussion

Basketball as a sport is filled with jump hops and intermittent sprints as attested to in earlier research (McInnes et al. 1996, pg. 394-396). The IG increased all jumps positively this we feel was due to the successive periodization of strength, since the IG had little to no strength training history, all gains would be positive as was the outcome. It's stated in the literature that strength gains mainly come from neuronal adaptation at an early phase of strength training (Bandy, Lovelace & McKitrick 1990, 248-255). As the intervention span was six weeks in length, this lead us to conclude that the majority of gains were due to neuronal adaptation. Strength training in combination with plyometrics recruits more type IIb muscle fibers which are well known for their power enhancing properties (Verkoshansky 1995, pg. 6).The athletes of the intervention group were in turn able to take advantage of this increased muscular force and thus improved jump height by 9-12 % in all vertical jumps, except in the DJ 60 which improved by 1%. The training intervention focused on drop jumps of 30 cm, given the status of the IG being inexperienced lifters the inclusion of training at 60 cm would be too intense/advanced for the IG. Looking at the law of specificity which pertains to being proficient within a skill, one would have to train that specific skill. Also the pre-post changes in contact times for all DJ according to the statistics were insignificant making the results possibly random. Contact times increased negatively in all DJ, we surmise that due to the shortened training length of the plyometric portion of the intervention that not enough time was given to reactive training.

5JT results were positive in that the group as a whole achieved an overall increase of 66 cm (6 %). The high correlation between the 5JT, vertical jump height, power output in the JSs and measured sprint ability (RSSA, YY IR1) suggests that it is an accessible test for coaches to evaluate a player's lower body strength.

The squat is an exercise that relies heavily on technique and joint flexibility, so that it can be carried out in a correct and injury free fashion. Although the 1RM squat is a great test for assessing lower limb strength of experienced lifters, all subjects in the present study were inexperienced with resistance training. Therefore we considered the 1RM squat to be a test that might endanger the athletes due to their inexperience of lifting and also might not measure the intended parameter. Squatting using a smith machine does not require the same technique or range of motion, and therefore we considered it to be the safest test to estimate young and inexperienced lifters maximum lower limb strength. Pre-post comparison of the IGs JS 50, 100, and 200% bw revealed positive increases in relative power production 17, 15 and 93 % respectively. We feel that the strong learning curve coupled with the fact that the subjects became accustomed to resistance training imparted confidence in their ability to lift heavy weights. This we believe was the contributing factor to all participants being able to lift twice their body weight as well as the effects of the periodized resistance training.

Results for the T-test showed significant improvement of 7 % in a reduction of test time to 8.9 sec which is equal to the times exhibited by elite college basketball players in the USA (Hoffman, Tenenbaum, Maresh & Kreamer 1996, pg. 68). We believe that the combination of strength training combined with agility exercises resulted in the positive decrease in time. This is in line with an article expounding the positive effects strength training has on agility (Mcbride et al. 2002, pg. 79).

The shortened shuttle time and the reduced fatigue index in the RSSA was in line with studies which verify that high intensity sprint training conducted twice a week, as in this study can lead to increased repeat sprint performance and increased agility (Walklate et al. 2009, pg. 1480), although minimum shuttle sprint time remained largely unchanged. This leads us to theorizing that the strength gains made from the squat training were not fully realized in sprints because of the unchanged reactive force. Previous studies also have revealed the pacing strategy used by athletes in the RSSA test as a means to complete said test. An earlier study verified that squat training increases 0-10 m speed but decreases 10-20 m speed, this can be explained by simple biomechanics, the concentric phase of the squat is similar to the acceleration phase of sprinting. Thus transfer of training movement will be accelerative in nature which is in line with the sport of basketball sprint durations 2-4s in length (Spencer et al. 2005, pg. 1027-1028). We feel the reactive force scores did not change in the subjects due to the lack of training time given to the plyometric training portion in the intervention, although in the earlier research studies, the scientists all had positive results with the test subjects with training times of 6 weeks (Adams et al. 1992, pg 39).

The YYIR1, test revealed that the IG participants increased the covered distance by 463 m (33 %). This we theorize was in part due to the possible aerobic capacity gains from the RSSA training (Buchheit, Bishop, Haydar, Nakamura F & Ahmaidi 2010, pg. 404-406). This coupled with self efficacy in the task led to improvement in distance covered in comparison with the pre test.

Given the obtained correlation between squat strength, sprint and vertical jump ability in the study which is in line with existing research (Wisloff, Castagna, Helgerud, Jones & Hoff 2004, pg. 285-288) it is clear that strength training should be an obligatory part of every basketball players training routine if the aim of the training is to improve.

The results from the repeated measures ANOVA showed in-between group differences in the pre tests which demonstrate better physical prowess in the CG. This was not accounted for in selection of the participants. We can only theorize that their previous training was of superior content. Post test results indicated no significant differences between both groups. We surmise that these results were due to the positive physical effects of the IG intervention, leading to diminished physical differences between groups in comparison to pre test results.

There were certain limitations to the study, such as the control of intensity and volume of training conducted by the athletes outside of the intervention. The dietary intake of the athletes was also unsupervised throughout the intervention. The CG had a greater physical status than the IG as the results of the pre test revealed; this makes it harder for the CG to gain positive effects of training and can be a contributing factor for the lower post test results (Ratamess et al. 2009, pg. 687-689). One subject of the IG had recently returned from an ankle injury upon the commencement of the intervention. His pre post test scores we feel could have affected the overall results due to him not reaping the full benefits of the intervention. There was a large dropout rate due to the exclusion clause; it would have been preferable with larger test groups so as to make the study more conclusive.

Strength training programs should be specific to the individual and the sport. A coach that shuns research and strength training through lack of knowledge, hinders an athlete's development and thereby performance. Great strength is the foundation of speed and power, and with this as a base an athlete can excel within their sport and surpass their previous abilities. This brings us to the all important training triangle which pertains to the interaction between scientific research, coach and athlete. With scientific research we mean that leaps forward in regard to human performance and physiology are being made within the research branch of sports science and these needs to be addressed and incorporated within the athletes training program. The coach in this equation needs to read and apply the advances made in the scientific fields of physiological research for the athlete's advancement and not just regurgitate previous training protocols without understanding the methodologies behind said training. In other words the coach should have an aim to the training as well as why this training should be done and also how to reach the goal of said training. The third part of the equation is the athlete, without the knowledge imparted by the coach from research and previous education, development of athletes will be sporadic. Without athlete and coach sports research will cease to develop, it is the culmination of coach and athlete developing in unison new training methods that sport science can either validate as reliable or reject as ineffective. Thus the triangle is interdependent, with one no more important than the others.

This being said, we believe that even a well constructed periodized strength training program based on scientific research will not reach its full potential unsupervised. The effects would probably be random as is the case in the present study's CG. In training as life in general it is not only important what you do, but HOW you do it to succeed!

Conclusion

This study evaluated the effects of a 6-week complex training intervention consisting of sprint training, squats, plyometrics, and repeated shuttle sprints. The main result of this study is that an in-season complex training regime induces positive effects on jump performance, agility and repeated shuttle sprints all of which are essential characteristics of Basketball. (Hoffman & Kang 2003, pg. 112-113; Santos & Janeira 2008, pg. 906-907; Mihalik et al. 2008, pg. 50-51; Ratamess et al. 2009, pg. 687-689)

Practical Applications

The results of this study imply that a more thorough strength training program would be beneficial for Swedish intermittent sports practitioners. Complex training not only improves power it is also time effective, the combination of resistance training with plyometrics in one session makes it a viable in season training regimen. These improvements are crucial within basketball since the sport is complex in nature. This should lead strength and conditioning professionals to address the positive benefits of complex training so as to bring about optimal gains in the performance of their athletes. Complex training challenges an athlete to be able to apply force through different ranges of motion due to the plyometric component, which leads to an induced degree of explosive power. Due to its intensity this type of training should always be supervised and monitored by seasoned professionals within the strength and conditioning branch.

In closing the acute effects off complex training have been noted in the present and past studies (Santos & Janeira 2008, pg. 906-907; Mihalik et al. 2008, pg. 50-51). We feel that a longitudinal study would be beneficial to further investigate the long term effects of this type of training on athletes.

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Attachment 1

Parental consent for study and test participation

Study

The tests are part of a training study conducted by students at The Swedish School of Sport and Health Science (GIH). All results will be handled confidentially, and will be presented so as not to reveal the identity of participants. If any queries arise do not hesitate to call test-leaders:
Juan Alonso: 0708688889 or Georgy Dias-Johnson: 0737000481

The subject participation is free of will. At any time subject is able to withdraw from the tests without giving an explanation.

Description of the tests performed in the study:

SquatJump*(SJ)*

The SJ test consists of performing a single jump with maximal effort from a semi-squat position.

Counter Movement Jump (CMJ_a)

The CMJ_a test consists of performing a single jump with a maximal effort from an erect position i.e. straight legged. The subject is free to use an arm swing.

Optimal Drop Jump *(ODJ)*

The test consists of stepping off and dropping from different raised platforms (i.e. 20, 40, 60 cm) and upon landing, immediately performing a vertical jump.

5 Jump test*(5JT)*

The test consists of five horizontal jumps for length, alternating one legged jumps but starting and finishing the jump sequence with parallel feet.

Jump Squat (JS)

The test consists of an explosive concentric movement in a smith-machine, from the start position at 90° knee angle with an external load equal to the 50 %, 100 % and 200 % of their body weight.

T-test

The purpose of the T-Test is to assess the agility of athletes, and includes side shuffling, forward, and backward running in a t-shaped manner.

Repeated Shuttle Sprint Ability (RSSA)

The test consists of six 20 meter shuttle sprints with a 20 second rest time between each bout.

Yo-Yo Intermittent Recovery Test Level 1 (YY IRT L1)

The test consists of 20 meter shuttles with 10 seconds of active recovery between each bout. The speed is increased progressively until subject is unable to complete the bout within the time frame.

I here by give ……………………………….. consent to participate in the described tests.

Stockholm /

______________________ ______________________

Parental signature **Subjects signature**

Attachment 2

Literature search:

Aim and questions:

This study aims to evaluate the physiological effect of two weekly in-season training sessions consisting of a combination of squats, plyometrics, sprint training and repeated shuttle sprints over a period of six weeks upon Swedish division 2 basketball players. To reach the aim of the study the following question was used

- *What is the effect of an intervention of six weeks of combined training on the physical characteristics of Swedish young basketball players?*

Words used in the literature search

Basketball
Training
Complex
Plyometric
Strength
Repeated shuttle sprints
YoYo test
Physical evaluation
PAP

Databases used

PubMed
EasySearch - Karolinska Institutet University Library
Google Scholar

Relevant search strings

PubMed - Basketball strength training
PubMed – Repeated shuttle sprints
PubMed – YoYo test
EasySearch – Basketball complex training
EasySearch – Physical evaluation basketball
EasySearch – Strength training and basketball
EasySearch – Plyometric training and basketball
Google Scholar – PAP and complex training

Commentary

The database at Karolinska Institutet University Library was very useful as they are subscribers of the electronic journals and thereby providing full text PDFs.