CHANGES IN STRENGTH AND ENDURANCE PERFORMANCE DURING A COMPETITIVE SEASON IN FEMALE BASKETBALL PLAYERS: Strength training sessions before vs. after sport specific training

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ABSTRACT

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Because of the conditions of most semi-pro leagues, teams and players often cannot train optimally. Practice times are inconsistent and strength trainings have to be held either before or after sport specific training. The aim of this study was to find, whether the in-season resistance training is more beneficial to be performed before or after sport specific training, or does the timing has any effect at all to the physical performance of players. In addition, how a certain type of resistance training program will affect the performance during the competitive season.

The measurements were done during the competitive season (Fall 2011 – Spring 2012). Subjects of this study (n=17) were divided into two groups, S+B (strength + basketball), age 20 ± 4, body weight 62,8 ± 7,8 kg, height 170,7 ± 5,8 and B+S (basketball + strength), age 18,7 ± 2,7, body weight 72,3 ± 13,7 kg and height 174,9 ± 2,6 cm. The measurements were done three times and included before the season measurements (B-SEA) (20-24.9.2011), mid-season measurements (M-SEA) during the Christmas break (7-15.12.2011), and post-season measurements (P-SEA) within a week when the season ended, 17-18.4 2012 (junior team players) and 21-22-5.2012 (women team players).

A statistically significant change ($p<0.05$) was observed in the squat in the S+B-group from the B-SEA value of 75 ± 18 kg to the P-SEA value of 90 ± 24.6 kg. A significant change ($p<0.05$) was noticed in the bench press, from the B-SEA value of 41.1 ± 8.8 kg to the P-SEA value of 45 ± 8.6 kg. A significant change ($p<0.05$) was observed in the squat in the B+S-group from that of B-SEA 74.4 ± 18.6 kg to M-SEA 81.8 ± 20.2 kg. Also a significant change ($p<0.05$) was found in the clean from M-SEA 45 ± 11.7 kg to P-SEA 47.5 ± 10.9 kg ($p=0.049$), but not in B-SEA – P-SEA. No significant ($p<0.05$) changes were observed in 20meter or endurance test run times in neither of the groups. In the B+S-group jump tests, a significant change ($p<0.05$) was found in FJ from that of M-SEA 36.5 ± 4 cm to P-SEA 38.3 ± 3.9 cm. There was a significant change ($p<0.05$) in the B+S-group average force (N) values in 500-1500ms from that of B-SEA 2157 ± 622N to P-SEA 2451 ± 526N. Also a significant change ($p<0.05$) was found on average force 0-500N and 500-1500N M-SEA – P-SEA values, 0-500N (M-SEA 1598 ± 333 N to P-SEA 1881 ± 440 N) and 500-1500N (M-SEA 2160 ± 384 N to P-SEA 2470 ± 513 N).

The findings suggest that the subjects were able to maintain or improve physical fitness level (strength and endurance) during the competitive season. According to the present results, it seems that strength training before the sport specific training is more beneficial during the competitive season.

Keywords: Basketball, combined training, order effect.

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1 INTRODUCTION

Resistance training increases muscular strength and power and it is an integral part of competitive athletics. Regular strength training during the competitive season can increase vertical jump height and power in women basketball athletes (Häkkinen, 1993), whereas the lack of in-season strength training results in a decrease in explosive force production of the leg extensor muscles in male basketball athletes (Häkkinen, 1988). Increased jump height and power is beneficial to a basketball athlete. However, a prevalent idea in athletics is that strength training on the same day as a game is detrimental to performance. Heavy strength training is usually avoided one day before and on the game days, which may interfere with a regular strength training schedule and may influence the benefits of resistance training.

Acute neuromuscular fatigue can be defined as a reduction in the force-producing capacity of the muscle (peripheral fatigue) and a decrease in the neural activity of the muscle (central fatigue) following a bout of exercise. Different studies have shown that heavy resistance exercise results in acute neuromuscular fatigue in both strength-trained and untrained men and women. Moderate- or low intensity resistance exercise can also result in acute neuromuscular fatigue.

Because of the conditions of most semi-pro leagues, teams and players often cannot train optimally. Practice times are inconsistent and strength trainings have to be held either before or after sport specific training. In this study it was the purpose to find, is the in-season resistance training more beneficial to be held before or after sport specific training, or does the timing affect at all to the physical performance. In addition, how a certain type of training program will affect the performance during the competitive season.

The competitive (regular) season in the Finnish female top league lasts from 2.10 to 12.3 (Suomen Koripalloliitto, 2010) and after that, playoffs for the top six teams. The total amount of games in the regular season is 28. The playoffs are played in best of five-series, starting from the quarterfinals, except for the top two teams from the regular season, who will advance straight to semi-finals. Regular season games are usually played once a week, with some exceptions, where there are two games a week. The season stops for 20 days during Christmas (19.12 – 8.1).

Less attention has been given to the thought whether the sport specific training and resistance training could be performed within the same session and how they should be divided. By trying to answer to this question, it might produce valuable information for all semi-pro league coaches and players on how to train during the competitive season.

2 IN-SEASON TRAINING AND ADAPTATIONS IN NEUROMUSCULAR AND ENDURANCE PERFORMANCE

2.1 Maintaining speed and strength abilities during the competitive season

A well designed and administered in-season strength training program is vital to the physical performance of athletes. This is the time when the increases in physical performance from the offseason must be maintained during the rigors of 2-a-day practices and the competitive season. According to Wathen et al. (2000), the goals of in-season strength training programs may include maintenance or increase (if possible) in strength, power, and anaerobic endurance. (Allerheiligen et al, 2003).

2.2 Explosive strength training

Heavy loads are fundamental to power development, because high forces are associated with maximal motor unit recruitment according to the size principle, with units also firing at higher frequencies (Behm, 1995; McDonagh, 1984). High force development may also inhibit force-feedback reflexes from the Golgi tendon organs or improve the synchronization of motor unit firing (Häkkinen, 1989; Komi, 1986; Sale, 1992).

In order to produce further increases in maximal voluntary neural activation of the muscles, the training intensity should be kept very high or maximal (e.g. 80-90-100% of 1 RM) and/or at progressively increasing levels. (Kraemer & Häkkinen, 2002). McArdle et al. (2010, pp. 503) suggests, power training done with high loads, >80% of 1RM for strength and 30-60% of 1RM for velocity. Number of sets and repetitions should be 1-3 sets and 1-6 repetitions for high loading and 3-6 sets and 1-6 repetitions for velocity training, depending on the level of the athlete.

When the number of repetitions (e.g. 1-3) is low in each set with very heavy loads, muscular hypertrophy may remain relatively minor, this is of advantage for many sports, because this type of training may lead to some increases in maximal force per CSA of the muscle. (Kraemer & Häkkinen, 2002)

2.3 Speed training

Explosive resistance training which utilizes lower loads but with high movement velocities results in improvements in all force portions of the *force-velocity curve*, but changes in the high force portions are smaller than during typical resistance training. (Kraemer & Häkkinen, 2002)

The effect of training on the shape of the force-velocity curves is related to the loads and velocities used. In power training loads are usually much lower (30-60% of 1 RM) than in heavy resistance training but contraction velocities are much higher. (Kraemer & Häkkinen, 2002; McArdle et al, 2010, pp. 503). This type of training results in improvements in all portions of the force-velocity curve, but changes in the higher portions of the curve are smaller than during heavy resistance training. If training is very close to the velocity end of the curve, then the effect is primarily in the velocity characteristics. Power training also influences the force-time curve →changes are greater in the very early portions of the curve than in the high force portion. Maximal strength and explosive strength training regimes should be well spaced or even mixed and matched with the specific requirements of the sport and individual. (Kraemer & Häkkinen, 2002)

Muscle elasticity plays an important role in explosive force production and is a phenomenon incorporated in SSC exercises → the influence of power training is strengthened during SSC exercises in which very high contraction velocities are utilized. In contrast to heavy resistance training, power training which includes various specific jumping exercises results in great increases in tolerance to and utilization of the stretch loads. (Kraemer & Häkkinen, 2002)

2.4 Hypertrophic training

A requirement for training-induced hypertrophy is high tension of a muscle for a sufficient duration to produce signaling mechanisms for increased uptake of amino acids and enhanced synthesis of contractile proteins. (Kraemer & Häkkinen, 2002)

The continuous process of damage and repair during and between sessions may result in an overshoot of protein synthesis → the optimal degree of hypertrophy may be obtained by using heavy but submaximal loads (e.g. 60-80% of 1 RM) and by performing multiple repetitions (e.g. 6-12) in each set until concentric failure with a short recovery period between sets. (Kraemer & Häkkinen, 2002)

In terms of muscle growth, the development of large forces is also important to the remodeling of muscle tissue (protein synthesis and degradation) (Fowles et al, 2000). The development of large forces stimulates receptor and membrane sensitivities, and muscle growth factors, thereby triggering an increase in protein turnover and the accretion of muscle protein. Heavy loading, particularly when the muscle is actively stretched, may further mediate muscle tissue growth by inducing greater reversible tissue damage (such damage seems a stimulus to muscle hypertrophy). Given the importance of large forces to the adaptative process, heavy training loads would appear to offer the optimal stimulus to development of muscle power. (Crewther, 2005)

Women have lower basal testosterone levels and interindividual variance is greater. Due to this the ultimate degree of hypertrophy and strength development will most likely be less in women than men during prolonged hypertrophic strength training of several months or years. (Kraemer & Häkkinen, 2002)

Gender-related differences in hormonal response to resistance exercise (e.g., increased testosterone and decreased cortisol for men) may determine any ultimate gender differences in muscle size and strength adaptations with prolonged training. (McArdle, et al, 2010, pp. 527).

2.5 Plyometric training

For sports that require powerful, propulsive movements, athelets apply a special form of exercise training termed plyometrics or explosive jump training. Plyometric exercise requires various jumps in place or rebound jumping to mobilize the inherent tretch-recoil characteristics of skeletal muscle and its modulation via the stretch or myotatic reflex. Plyometric exercise involves rapid stretching followed by shortening of a muscle group during a dynamic movement. Stretching produces a stretch reflex and elastic recoil within muscle. (McArdle, 514. 2010).

In basketball, the ability to generate maximal strength levels in the shortest period of time (muscular power) has been considered as essential to obtain high sport performance levels. Moreover, strength training is part of basketball preseason programs with a background of related benefits that improve sport performance, reduce injury rate, and provide higher motivation levels for the athletes. Two methods, resistance and plyometric training, are usually referred to in the literature as improving the most powerful strength characteristics (explosive strength) in basketball players. Several investigations have demonstrated the positive effects that result from the application of these methods, reporting higher increases in the explosive strength indicators. Conversely, significant decreases occurred in the vertical jump ability of young basketball players following 15 weeks weight training program. (Eduardo et. al. 2008).

Plyometric training activities are commonly used by a wide range of athletes to improve explosive power. The principle of specific adaptations to imposed demands illustrates that when training to exert maximal power, improvements will be suboptimal when training at submaximal power. Still, many plyometric training sessions for inexperienced participants are administered at volumes well in excess of the recommended maximum of between 80 (novice) and 140 (advanced) ground contacts per session. However, the effects of high-volume plyometric training programs on voluntary and evoked contractile properties such as rate of force development and muscle activation are unknown. (Drinkwater et. al. 2009).

Plyometric training is intended to maximize the efficient transition from the eccentric to concentric phase of a contraction, a sequence referred to as the stretch-shortening cycle (SSC), and depends on using (passive) elastic energy in the muscle and the (active) myotatic reflex. Plyometric training can impart on the active muscle groups’ eccentric loads in excess of 5 times the participant’s body weight, generating a force well beyond that which could be voluntarily produced. (Drinkwater et. al. 2009)

Plyometric exercises range in difficulty from calf jumps off the ground to multiple one-legged jumps to and from boxes ranging in height from one foot to six feet. The basic principle for all jumping and plyometric exercises is to absorb the shock with the arms or legs and then immediately contract the muscles. (McArdle, 514. 2010).

Research must quantify the appropriate role of plyometric drills in a complete strength-power training program, particularly for children and older recreational athletes. A position paper from the National Strength and Conditioning Association (www.nsca-lift.org) suggests that athletes first achieve lifts of 1.5 times bodyweight in the squat exercise before initiating high-intensity plyometric training. (McArdle, 516. 2010).

Using voluntary and evoked muscle characteristics, Drinkwater et.al. (2009) found that although there was no significant change in muscle activation immediately after the plyometric training session, there was evidence of peripheral but not central fatigue. A moderate decline in the rate of twitch torque development, thus indicating a slowing of contraction velocity was also observed. It was concluded, that high-volume plyometric training results in substantial peripheral fatigue and slows contraction velocity, even when the training session is not exhaustive. (Drinkwater et.al. 2009)

Complex training, a method that combines resistance training and plyometrics, has been proposed to increase muscular power. Upper and lower body explosivity levels of basketball players can be improved with a combined program of plyometrics and resistance training. (Eduardo et. al. 2008).

Table 1. A complex training program including resistance and plyometric training. (Eduardo et. al. 2008).

Table 1. Resistance and plyometric training protocols.

	Session 1		Session 2	
Resistance training	Weeks 1–2	Weeks 3–10	Weeks 1–2	Weeks 3–10
Leg extension	2 × 10/12 RM	3 × 10/12 RM		
Pullover	2 × 10/12 RM	3 × 10/12 RM		
Leg curl	2 × 10/12 RM	3 × 10/12 RM		
Decline press			2 × 10/12 RM	3 × 10/12 RM
Leg press			2 × 10/12 RM	3 × 10/12 RM
Lat pull down			2 × 10/12 RM	3 × 10/12 RM
Rest between sets: 2–3 min; rest between exercises: 45–60 s				
	Session 1		Session 2	
Plyometric training	Week 1	Week 2	Week 1	Week 2
Rim jump	2 × 10 reps	3 × 10 reps		
MB squat toss	2 × 10 reps	3 × 10 reps		
Zigzag drill	2 × 10 m	3 × 10 m		
2-foot ankle hop			2 × 15 reps	3 × 15 reps
MB chest pass			2 × 10 reps	3 × 10 reps
Squat jump			2 × 10 reps	3 × 10 reps
Rest between sets: 60 s; rest between exercises: 15 s				
	Weeks 3–4			
Tuck jump	3 × 10 reps			
MB overhead throw	3 × 12 reps			
Alternate leg push-off	3 × 10 reps			
Single-arm alternate-leg bound			3 × 10 m	
MB backward throw			3 × 10 reps	
Lateral jump over cone			3 × 10 reps	
Rest between sets: 60–90 s; rest between exercises: 15–30 s				
	Week 5	Weeks 6–7	Week 5	Weeks 6–7
Side jump/sprint	3 × 6 reps +5-m sprint	4 × 6 reps +5-m sprint		
MB seated chest pass	3 × 10 reps	4 × 10 reps		
Lateral box jump	3 × 10 reps	4 × 10 reps		
Depth jump			3 × 6 reps	4 × 6 reps
MB seated backward throw			3 × 10 reps	4 × 10 reps
Hurdle hops			3 × 5 reps	4 × 5 reps
Rest between sets: 2–3 min; rest between exercises: 60 s				
	Weeks 8–10			
Depth jump 180° turn	4 × 6 reps			
MB pullover pass	4 × 10 reps			
Hurdle hops	4 × 8 reps alternate lateral/frontal			
Cone hops with change of direction sprint			4 × 6 reps +5-m sprint right/left	
MB power drop			4 × 10 reps	
Multiple box-to-box jumps			4 × 6 reps	
Rest between sets: 3–4 min; rest between exercises: 60–90 s				

RM = repetition maximum; reps = repetitions; MB = medicine ball; sets × reps.

Khlifa et. al (2010) suggests, that plyometric training with added loads of 10-11% of body mass, enhance performance on jumping tasks on young female basketball players. Jaakkola (2008) reported that the use of weighted wests wore 24hrs a day resulted in enhanced performance. Also the effect of detraining was studied, and the effects gained by wearing the weighted west were no longer statistically significant after three weeks.

2.6 Endurance training/sport specific training

Efstratios et. al (2007) suggest that basketball practice itself is enough to maintain or improve endurance performance throughout competitive season.

Montgomery et al (2010) found that Defensive and offensive drills during basketball practice have similar physiological responses and physical demand. Live play is substantially more demanding than a 5on5 scrimmage in both physical and physiological attributes.

Balciunas et al (2006) found that basketball practice alone was enough to maintain endurance performance. Nevertheless, added endurance training was needed for gains in endurance performance.

2.7 Programming

Periodization varies training intensity and volume to ensure that peak performance coincides with major competition. It also proves effective for achieving recreational and rehabilitative goals. Periodization subdivides a specific resistance-training period such as 1 year (maacrocycle) into smaller periods or phases (mesocycles), with each mesocycle again separated into weekly micro cycles. Periodization variation can reduce negative overtraining or “staleness” effects so athletes achieve peak performance at competition. (McArdle, 503. 2010).

A common model for periodization is divided into three or four major phases or cycles; Preparation phase, First transition phase, Competition phase and Second transition phase (active recovery). (McArdle). In basketball these phases are more commonly discussed as Off-season, Pre-season and In-season. Off-season includes both the end of in-season which includes rest and active recovery and the phase before pre-season. (Krause & Pim, 121. 2002).

Preparation phase emphasizes modest strength development with high-volume (3-5 sets, 8-12 reps), low-intensity workouts (50 to 80% 1RM plus flexibility, aerobic and anaerobic training).

First Transition phase emphasizes strength development with workouts of moderate (3-5 sets, 5-6 reps) and moderate intensity (80 to 90% 1RM plus flexibility and interval aerobic training).

Competition phase lets the participant peak for competition. Selective strength development is emphasized with low-volume, high-intensity workouts (3-5 sets, 2-4 reps at 90-95% 1RM plus short periods of interval training that emphasizes sport specific exercises).

Second transition phase emphasizes recreational activities and low-intensity workouts that incorporate different exercise modes. For the next competition, the athlete repeats the periodization cycle

Professional Basketball has been reported to impose important physiological loads on players during competition. Consequently, physical conditioning is considered as a prerequisite to compete at elite level in modern basketball. To increase the fitness level of athletes, the training loads (TLs) should be accurately prescribed to induce sport-specific physiological adaptations. Many studies have stressed the importance of varying the daily and shortmedium term TLs (i.e., alternation of hard and easy periods of training) to achieve optimal performance. Given that, coaches and fitness trainers periodize their training interventions to achieve the set performance goals. (Manzi et. al. 2010)

Differently from endurance sports where TLs are prescribed on individual bases, in team-sports TLs are often similar for each player because of the extensive use of group drills. Consequently, the training response (internal load) to a given imposed load (external load) may result in being different among players. This occurrence is of importance for the coach and fitness trainer because extreme training responses (i.e., low or excessive responses) may result in training maladaptations . (Manzi et. al. 2010)

Table 2. Weekly training load for Lottomatica Virtus Basket Roma –club professional basketball players. (Manzi et. al. 2010).

	Training activity		
Day	No game	1 Game	2 Games
Monday	Technical/tactical	Rest	Rest
Tuesday	Strength training + technical	Strength training + technical	Explosive weights + technical
Wednesday	Technical/tactical	Technical/tactical	Tactical
Thursday	Explosive weights + technical	Explosive weights + technical	Game
Friday	Technical/tactical	Technical/tactical	Tactical
Saturday	Tactical	Tactical	Technical/tactical
Sunday	Rest	Game	Game
Weekly load	3,334	2,928	2,791
Monotony (mean weekly load/*SD*)	1.70	1.59	1.62
Strain (load × monotony)	5,678	4,666	4,534

3 ACUTE NEUROMUSCULAR RESPONSES TO HEAVY RESISTANCE EXERCISE AND RECOVERY

The magnitude of neuromuscular responses can be considered as important indicators of training effects of various heavy resistance exercises. The performance of muscle gradually declines when muscles are used repeatedly at near their maximum force. This muscle fatigue is reflected in reduced force production, reduced shortening velocity and a slower time-course of contraction and relaxation (Allen 2004). Fatigue may be caused by diminished efferent neural command to activated muscles from the central nervous system (i.e. central fatigue) which inhibits exercise activity before any irreparable damage to muscles and organs occurs. Fatigue may also be caused by factors within the muscle cells (i.e. peripheral fatigue) (St Clair Gibson et al. 2001, Westerblad and Allen 2002).

3.1 Heavy resistance (neural) loading (1-3 RM)

Acute fatigue in the neuromuscular system observed as decreases in both maximal voluntary neural activation and in maximal force of the exercised muscles is related to overall volume, intensity and type of session, recovery between sets, muscle fiber distribution and training background. “Neural loading” (1-3 RM) decreases in strength after 8-10 sets (greater in men than in women) and both activation and maximal force decreases (peripheral and neural fatigue) - also decrease in explosive strength. Recovery depends on the loading, can take several days. (Kraemer & Häkkinen, 2002)

3.2 Explosive resistance loading (e.g. 30-60% max)

Acute decreases in maximal force and in explosive strength is indicated as changes in the shape of the force-time curve during the initial portions show acute decreases observed during 0-100 ms of the integrated EMG-time curve of the loaded muscles. Low post-loading lactate levels indicate that explosive type loading primarily results in acute central fatigue and/or impaired neuromuscular propagation. Recovery from session is related to overall volume and type of session, recovery between sets, fiber distribution, sex and training background. (Kraemer & Häkkinen, 2002)

An isometrically trained muscle shows greatest strength improvement when measured isometrically; similarly, a dynamically trained muscle tests best when evaluated in resistance activities that require movement. Resistance training specificity makes sense because strength improvement blends adaptations in two factors: the muscle fiber and connective tissue harnesses itself, and the neural organization and excitability of motor units that power discrete patterns of voluntary movement. (McArdle et al, 2010).

4 NEUROMUSCULAR ADAPTATION

Training induced adaptations in the neuromuscular system

The production of maximal force and power can also be termed “explosive strength” and involves several functional and structural components. Nervous system has a major role in activation and force production in the following order; central command, spinal cord and motor unit activation. The commands are modified by feedback from the periphery (sensory receptors) and higher level controllers (brain e.g. activation, coactivation). Strength and power training can have leads to specific adaptations in all of the compartments of the nervous system as well as in the muscle tissue itself. Several factors such as type, intensity and duration of the training period determine the nature and magnitude of training-induced functional and structural adaptations. (Kraemer & Häkkinen, 2002)

Adaptive alterations in nervous system function that elevate motor neuron output largely account for the rapid and large strength increases early in training, often without an increase in muscle size and CSA. Neural adaptations play a particularly important in the muscular strength and power improvements with resistance training. (McArdle et al, 2010, pp. 519)

5 TRAINING ORDER

5.1 Endurance vs. resistance training

It has been relatively solidly established that concurrent strength and endurance training with an overall high volume to some degree hinders the gains in strength and the physiological adaptations that typically occur with single-mode training (eg. Kraemer et al. 1995; Leveritt et al. 1999; Chtara et al. 2008).

Still debate concerns whether concurrent resistance and aerobic training yields less muscular strength and power improvement than training for strength only. Advocates for abstaining from aerobic training when attempting to optimize gains in muscle size and strength maintain that the added energy (and perhaps protein) demands of intense endurance training limit a muscle's growth and metabolic responsiveness to resistance training. Endurance exercise training may inhibit signaling to the muscles' protein-synthesis machinery, which would definitely be counterproductive to the goals of resistance training. (McArdle, 505. 2010).

The main difficulty with a combined training regimen seems to be the development of strength. Both the structural properties of the muscle as well as the endocrine responses seem to be affected differently by concurrent strength and endurance training than by either strength or endurance performed alone. (eg. Hickson 1980, Bell et al. 2000.)

Less interference in performance adaptations seems to occur in well-trained individuals, likely due to a higher tolerance for long-term combined training (Hunter et al. 1987). Nevertheless, priorities regarding the main goal of training and the desired adaptations should be taken into account by periodizing training programs accordingly (Häkkinen et al. 2003).

5.2 Exercise order

Studies have shown that by exercising larger muscle groups first, a greater intensity or more effective training stimulus can be put on all of the muscles involved in an exercise, therefore it is preferred to use structural/multi-joint exercises first in the workout followed by smaller single-joint exercises. In addition, performing more complex multi-joint exercises (e.g. power cleans) first, may enhance learning and mastery of technique (focus and fatigue). (Kraemer & Häkkinen, 2002)

Spineti et al (2010) debates, that exercises that are particularly important to the client should be placed at the beginning of an exercise session. Additionally, if an exercise is important for the training goals of a program, then it should be placed at the beginning of the training session, regardless of it being a large or small muscle group exercise. In this approach, the immediate need of the client receives greater emphasis in program design than the traditional large to small muscle exercise sequence. Because weaknesses in smaller supportive muscles can limit the performance of more complex exercises, increased focus on those smaller muscles (if they are found to be a limiting factor) early in an exercise session would be expected to have a positive impact on the performance of complex exercises over time.

Different exercise orders to the previously mentioned are obviously also possible and may have their own rationale and support for their use, e.g. when sport performance requires one to perform maximal whole body power movements under fatiguing conditions(e.g. ice hockey), one may place e.g. power cleans at the end of the workout. This would help to enhance and evaluate power production under fatiguing conditions that are similar to the sport's metabolic conditions. (Kraemer & Häkkinen, 2002)

The Pre-exhaustion methods use this method and reverse the order of the exercises so that the small muscle groups are exercised prior to the lager muscle groups and creating fatigue in the muscles needed in whole body exercise movements. Another method for pre-exhaustion is to fatigue the synergists or stabilizing muscles before performing the primary exercise movement. This typically results in a lower amount of weight that can be used in the whole body exercises and the advantages and disadvantages of pre-exhaustion exercise order in optimizing strength and power gains is highly speculative, but may help in developing functional strength and power under fatiguing conditions that mimic the sport performance (e.g. late in a game, later part of a 400m sprint). (Kraemer & Häkkinen, 2002)

The priority system has also been used widely in resistance training. When using the priority system, the session for the day will focus on one or two particular exercises. Exercises are prioritized and performed first or early in the session to ensure focus on the goals for each session. Power type exercises (e.g. power cleans and plyometrics) should be performed early in the session, which allows the athlete to develop and train maximal power prior to becoming fatigued. Performing power type exercises in the end of the workout may have some rationale by evaluating and developing power under fatiguing conditions (if needed in the sport performance). (Kraemer & Häkkinen 2002).

In circuit training “arm-to-leg” ordering of exercises is most common to allow some recovery of the arm muscles while the leg muscles are exercised and vice versa. Pre-exhaustion, arm-to-arm/leg-to-leg protocols may be used, but must be used wisely (tolerance). One major notification is also the fitness level of the individual. Training sessions should never be designed to be too stressful for the individual, especially if he/she is just starting to use resistance training. Exercise order can have a significant impact on the training stimulus stress level. (Kraemer & Häkkinen 2002).

6 METHODS TO DETERMINE PHYSICAL PERFORMANCE IN BASKETBALL PLAYERS

Anaerobic performance tests are used to assess speed, acceleration, explosiveness and repeated short bursts of efforts, which as indicated are all important components of basketball. Variations of the vertical jump test (Isaacs 1998, Stapff 1998) are familiar tests within the literature to measure explosive power in the legs and also a skill which is highly functional to basketball.

The vertical jump is cost effective and simple test, which is very specific to the requirements of basketball which require jumping in all aspects of the game. The main skills involving jumping include the lay up, jump shot, rebound, shot block and intercepting passes. McInnes et. al (1995) notes that high intensity type activities like jumping occur approximately 15 % of the total active time. Therefore the vertical jump test can be used effectively as a measure to demonstrate changes from either jumping specific training or a specific lower limb strengthening exercise program (McArdle et. al, 2010).

Vertical jumps tests represents of the lower limbs ability to generate power. The most common vertical jumps are squat jump (SJ) and countermovement jump (CMJ). When performing jumps on a contact mat, the height of the jump is calculated from flight time (Kyröläinen, 2007). The inclusion of the arm swing in the test procedures does complicate the specific testing of leg power as the arm swing is thought to contribute approximately 10% to the jump height (Luhtanen and Komi, 1978). The extensor muscles of the hip, knee and ankle are still the main contributor to this action and Wilson and Murphy (1995) believe the vertical jump tests of muscular function are significantly related to dynamic performance levels.

Muscular strength is also regularly assessed due to its importance within a game. Because basketball requires numerous skills, which must be applied dynamically, explosively and repeatedly muscular strength of the arms and legs are both important to consider. The bench press and squat are the two most common tests used, as the patterns of movement are very similar to aspects of the game (Bridle 1999 Stapff 1998).

Finnish basketball association (Suomen Koripalloliitto, 2010) uses 3RM in national team testing, including junior teams and men’s and women’s national team testing. 3RM testing is more sport specific, since in basketball player has to perform a task (jumping etc.) multiple times in a short period of time, rather than once. Also the 3RM testing allows lighter weights to be used and thus decreasing the risk of injury during testing.

Nevertheless, 1RM effort is considered as golden standard for evaluating strength, but RM testing can involve any number of repetitions. 1RM is exercise specific, so values are different between exercises. 1RM testing is a good way to determine loads to resistance training. Test-retest reliability of 1RM testing is high. (Kraemer et.al 2006)

7 PURPOSE OF THE STUDY

The purpose of this study was to examine the changes in neuromuscular and endurance performance during the competitive season and within a single training session, and to compare differences between two groups which performed strength training before (S+B) and after (B+S) sport specific training. This study also investigated relationships between physical performance and sport specific performance.

Research problems:

1. Does the neuromuscular and endurance performance change during the season?
2. Is the in-season resistance-training more beneficial to be carried out before or after sport specific training?

8 METHODS

8.1 Training

Training of the players was periodized into three segments. During the first half of the competitive season, heavy and explosive resistance training was emphasized. In January, the emphasize was on hypertrophic loading and after that for the remaining of the competitive season the resistance training program returned into heavy and explosive loading (Appendix 1,2,3.).

Each basketball practice was always 75 minutes and included skill training such as shooting, dribbling and passing, scrimmage games and tactical preparation for the games.

During the competitive season, training loads were controlled so, that if a player had two games during a week (usually two games during a weekend) she would only do one resistance training session. If a player had one game during the week, she would do both resistance training sessions.

8.2 Subjects

Subjects were 17 healthy female basketball players. Subjects were divided into two groups by former experience (years) in resistance training and the skill level of players. The groups were S+B (strength + basketball), age 20 ± 4, body weight 62,8 ± 7,8 kg, height 170,7 ± 5,8 cm and B+S (basketball + strength), age 18,7 ± 2,7, body weight 72,3 ± 13,7 kg and height 174,9 ± 2,6 cm.

8.3 Measurements

Table 3. Study Design for measurements. B-SEA (before season), M-SEA (mid-season) and P-SEA (post-season) measurements.

Measurements included before the season measurements (B-SEA) (20-24.9.2011), mid-season measurements (M-SEA) during the Christmas break (7-15.12.2011), and post-season measurements (P-SEA) within a week when the season ended, 17-18.4 2012 (junior team players) and 21-22-5.2012 (women team players).The pre- mid- and post (SEA) measurements included all the same tests. The field tests included 20 meter sprint running, clean, squat and bench-press (1RM) and jump tests; countermovement jump (CMJ), static-jump (SJ) and free-jump (FJ). In free jump (FJ) subjects were allowed to gather speed from outside the contact mat and use arm swing. The beep-test was used for evaluating endurance performance. The acute measurements (explained in the chapter of acute measurements) included countermovement jump and maximal bilateral isometric leg extension. The laboratory measurements included body composition evaluation by bioimpedance (Inbody 720), countermovement jump and maximal bilateral isometric leg extension. The laboratory tests were performed in the department of Biology and Physical Activity, Jyväskylä University. The field tests were performed in Hipposhalli and on the basketball court of Monitoimitalo in Jyväskylä.

Subjects always had one full day of rest before any testing took place. Body composition evaluation took place for each player at the same time of day in all measurements to increase reliability.

8.4 Physical performance tests

8.4.1 Anthropometry

Body composition and weight measurement were performed with Inbody 720 device. Skeletal muscle mass (SMM), fat% and weight was measured. Subjects were instructed to remove jewelries or other medals from their bodies. Height was measured before the body composition analysis.

8.4.2 Neuromuscular and endurance performance

Maximal bilateral isometric leg extension force was measured by leg dynamometer build in the University of Jyväskylä by using 107 degree knee angle (Keskinen et. al.,2007., Häkkinen et. al., 1985). Knee angle were tracked by using goniometer. The subjects were told to produce force as fast and as much as possible. If the force improved over 5 %, more trials were performed. Proper recovery between the trials was allowed. Endurance performance was measured using the beep-test, which is used by the Finnish basketball association in national team testing (Suomen Koripalloliitto, 2010).

8.4.3 Field tests

All jump tests (CMJ, SJ and FJ) were performed on the contact mat. The test was chosen to measure power of lower extremities (Komi & Bosco, 1978.) Subjects were instructed to stand hands on their hips in a comfortable starting position. From this position in countermovement jump, subject bended her knees, hips and ankles and then immediately jumped as high as possible. Subjects were instructed to land legs straight to the ball of the foot. In static jump subject bended her knees, hips and ankles, paused the movement at the squat position and then jumped as high as possible. In free jump, subjects developed speed outside the contact mat, approached the mat and jumped into the mat and landed in the same way as in the previous jump tests. Arm movement was allowed. Each subject performed at least three jumps in each jump test with proper recovery.

20 meter sprint running were performed on indoor running track. Time was measured with light cells. Each subject performed at least three sprints with proper recovery.

1 RM was used in the clean, squat and bench-press testing (Kraemer et. al. 2006). In the clean, subjects could lift the weight either straight from the ground, or lift first as a deadlift and then lower the bar below knees and then cleaned. Every subject performed three trials and if her performance improved over 5 %, more trials were performed.

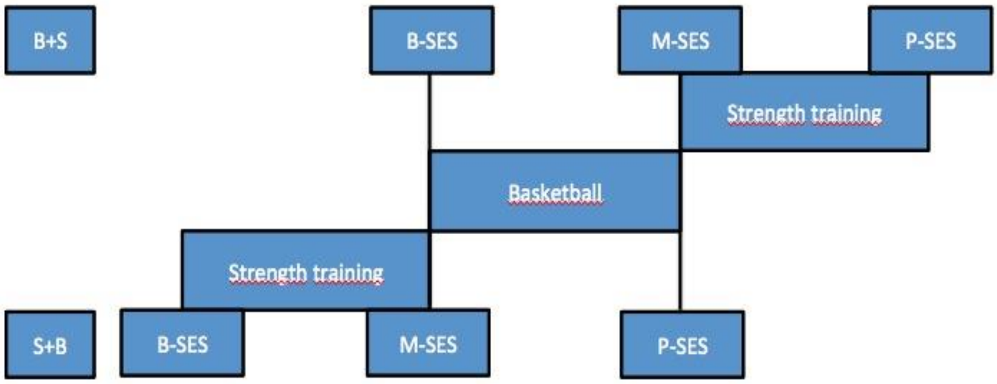
Squat was performed in a squat rack. A trial squat without weights was performed before the actual testing to determine knee angle (thigh at a horizontal level). A string, which the subject could feel as squatting, was deployed on the squat rack. Also, each squat was supervised to not allow too great knee angles.

Bench press was performed in the way that gluteus maximus had to stay on the bench during lifting.

All tests were done after adequate warm ups in the following order: 20m, CMJ, SJ, FJ, clean, squat, bench-press, beep-test.

8.4.4 Acute measurements

Table 4. Study desing for a single session acute measurements. B-SES (before-session), M-SES (mid-session) and P-SES (post-session).



The Acute measurements consisted of three measurements within a training session. The tests included before-session (B-SES), mid-session (M-SES) and post-session (P-SES) measurements. The S+B group was tested before session, after the resistance training session and after the sport specific training session. The B+S group was tested before sport specific training session, after the sport specific training session and after the resistance training session. All subjects performed the pre-session measurements after warm-up. All post-session (resistance or sport specific-tests) were performed within 4minutes after the session. The mid-session measurements were performed within 5minutes after resistance or sport specific training. The acute testing included countermovement jump and maximal bilateral isometric leg extension. All subjects were allowed to have three trials in CMJ jump test. The best result was recorded. On bilateral isometric leg extension MVC (kg) was recorded. All subjects were given three trials or if the result increased 5% on the last trial, additional trials were given until the force level no longer increased.

8.5 Statistical Analysis

All data was analyzed and graphed using Microsoft Excel 2011 (Microsoft Oy, USA) software and IBM SPSS Statistics v.20 software (SPSS inc.,USA). Microsoft Excel was used for calculations of means, standard deviations (SD), as well as for drawing graphs. Within group differences and between group differences were analyzed by repeated measures ANOVA, using SPSS software. Significances were set at $*p<0.05$ and $**p<0.01$.

9 RESULTS

9.1 Field tests

A statistically significant change (p<0.05) was observed in the squat in the S+B-group (strength+basketball) from the B-SEA value of 75 ± 18 kg to the P-SEA value of 90 ± 24.6 kg (P=0.008) (Table 5). Also, a significant change was noticed in the bench press (p=0.026), from the B-SEA value of 41.1 ± 8.8 kg to the P-SEA value of 45 ± 8.6 kg. No significant (p<0.05) changes were observed in the clean in the S+B-group from the B-SEA value of 43.3kg ± 9.1 kg to the POST value of 46.9 ± 9.5 kg.

Table 5. Clean, Squat and Bench press results. *=significant change (p<0.05) within group. B-SEA=Before the season; M-SEA=Mid-season; P-SEA=Post season.

		Group	Clean		Squat		Bench press	
			MEAN	SD	MEAN	SD	MEAN	SD
B-SEA		S+B	43.3	9.1	75.0	18.0	41.1	8.8
		B+S	44.4	10.0	74.4	18.6	41.4	11.9
	Change%	S+B	2.9%		17%*		1.1%	
	B to M-SEA	B+S	1.2%		8.97%*		4.2%	
M-SEA		S+B	44.6	9.7	90.4	18.1	41.6	8.9
		B+S	45.0	11.7	79.2	20.2	43.2	10.3
	Change%	S+B	4.8%		-0.4%		7.64%*	
	M to P-SEA	B+S	5.3%		-5.1%		5.3%	
P-SEA		S+B	46.9	9.5	90.0	24.7	45.0	8.6
		B+S	47.5	10.9	77.9	24.3	45.6	10.5
	Change%	S+B	7.6%		16.7%*		8.64%*	
	B to P-SEA	B+S	6.4%		4.4%		9.3%	

There was a significant change in the squat in the B+S-group (basketball+strength) from that of B-SEA 74.4 ± 18.6 kg to M-SEA 81.8 ± 20.2 kg (p=0.02). Also a significant change was found in the clean from M-SEA 45 ± 11.7 kg to P-SEA 47.5 ± 10.9 kg (p=0.049), but not in B-SEA – P-SEA.

There were no significant (p<0.05) changes in 20meter run times in neither of the groups (in the S+B-group B-SEA 3.44 ± 0.17s to P-SEA 3.421 ± 0.23s. B+S-group B-SEA 3.42 ± 0.17 to P-SEA 3.42 ± 0.23s).

No significant changes were observed in the endurance test (beep), although there was a 8.6% increase in laps completed from B-SEA 80.13 ± 11.9 laps to P-SEA 85 ± 13.9 laps. (Figure 1)

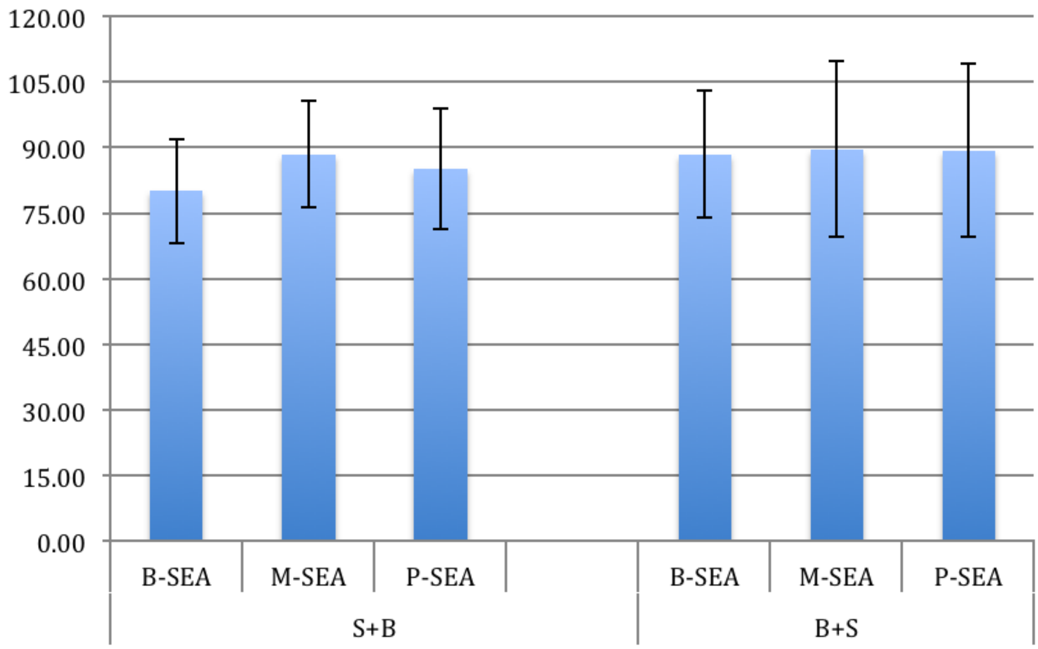


Figure 1. Endurance test (beep-test) performance (laps completed) in S+B and B+S groups.

In the jump tests of the S+B-group (counter movement jump. static jump and free jump), SJ approached a statistically significant change (p=0.051) from the B-SEA to the P-SEA comparison (Table 6). In the B+S-group jump tests, a significant change was found in FJ from that of M-SEA 36.5 ± 4 cm to P-SEA 38.3 ± 3.9 cm (p=0.041). FJ approached a statistically significant change (p=0.053) in the B-SEA – P-SEA comparison.

Table 6. Jump tests performance (cm) in the S+B and B+S Groups. *= Statistically significant change in M-SEA – P-SEA (p<0.05).

		CMJ		SJ		FJ	
		Mean	SD	Mean	SD	Mean	SD
S+B	Pre	30.1	5.9	28.5	4.2	41.4	9.3
	Mid	30.4	4.7	28.7	5.2	38.7	6.2
	Post	32.0	5.1	30.3	5.0	42.3	7.9
B+S	Pre	29.1	3.6	28.5	4.0	36.5	4.0
	Mid	29.8	2.8	28.1	3.5	36.5	4.0
	Post	31.0	3.0	29.3	2.9	38.3*	3.9

A statistically significant change was found in acute CMJ (Table 7) in the B+S group from that of M-SEA 27,2 ± 9,8 cm to P-SEA 31,8 ± 4,2 cm (p<0.05).

Table 7. Acute B-SES jump test performance in the S+B and B+S groups. *=Statistically significant change in M-SEA - P-SEA results (p<0.05).

Measurement	Change%	Group	Mean (cm)	SD
B-SEA		S+B	29,3	10,8
		B+S	27,1	12,4
	Change%	S+B	6 %	
	B-SEA - M-SEA	B+S	1 %	
M-SEA		S+B	31,2	14,8
		B+S	27,2	9,8
	Change%	S+B	-2 %	
	M-SEA - P-SEA	B+S	14%*	
P-SEA		S+B	30,7	14,6
		B+S	31,8	4,2
	Change%	S+B	5 %	
	B-SEA - P-SEA	B+S	15%*	

9.2 Anthropometrics

There were no statistically significant ($p<0.05$) changes in any of the anthropometrics tests (height, weight, fat% and SMM) in neither of the groups (Figure 2). In both groups, the height of the subjects remained the same during the B-SEA – P-SEA measurements. In the S+B-group, weight changed from B-SEA 62.8 ± 7.8 kg to P-SEA 63.5 ± 6.5 and in the B+S-group from B-SEA 72.3 ± 13.7 to P-SEA 71.22 ± 12.9 kg. The fat% values of the S+B-group changed from B-SEA 20 ± 2.8 % to P-SEA 19.84 ± 3.4 %, and in the B+S-group from B-SEA 23.9 ± 5.8 % to P-SEA 22.8 ± 4.8 % (Figure 3). In the S+B-group, skeletal muscle mass changed from B-SEA 28.12 ± 3.7 kg to P-SEA 28.34 ± 3.9 kg, and in the B+S-group from B-SEA 30.5 ± 4.9 to P-SEA 30.6 ± 5.2 kg.

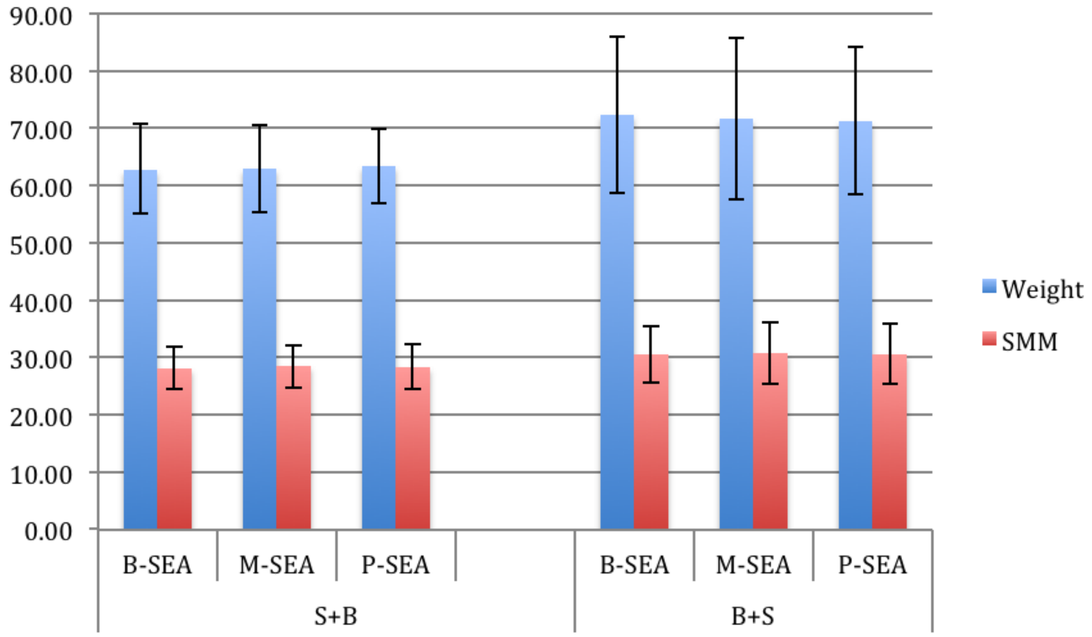


Figure 2. Weight (kg) and skeletal muscle mass (kg) (SMM) in the S+B and B+S groups.

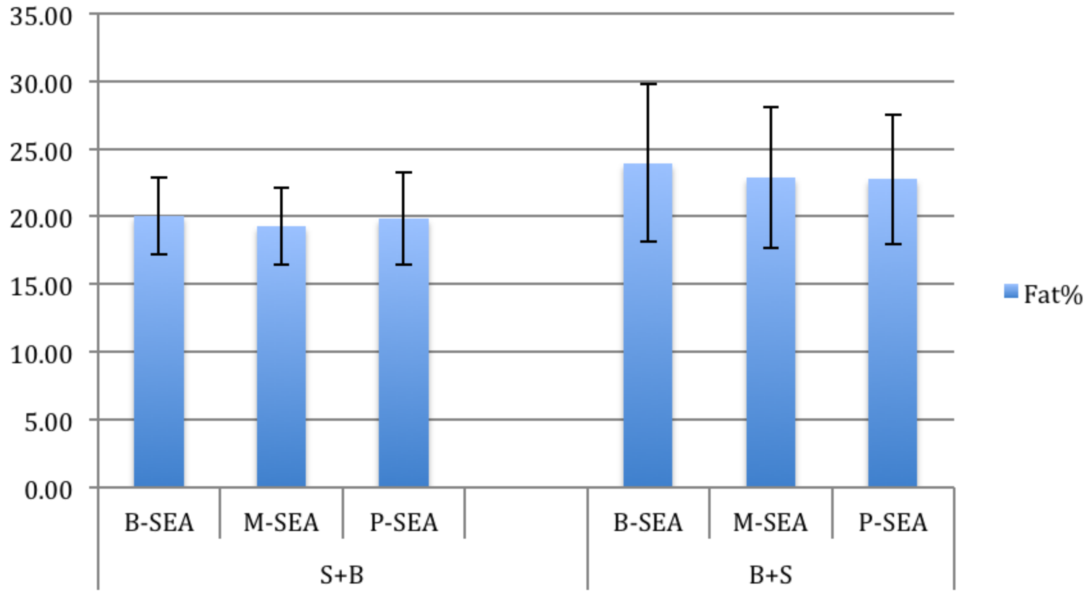


Figure 3. The fat% in the S+B and B+S groups.

9.3 Acute measurements

9.3.1 Counter movement jump:

There was a statistically different change ($p<0.05$) in the S+B-group in all jump tests between the B-SES – P-SES values (Figure 4). The B-SES -jump increased by 2.3%. M-SES -jump increased 3.3% and the P-SES -jump by 3.6%. Also there was a statistically significant change in the S+B-group B-SEA – M-SEA values in the B-SES- ($p=0.02$) and M-SES -jump ($p=0.0005$) tests. The values changed from that of B-SEA 29.2 ± 4.8 cm to M-SEA 31.1 ± 5.9 cm in the B-SES measurements. In the M-SES tests, the results changed from B-SEA 28.5 ± 4.7 cm to M-SEA 31.3 ± 5.6 cm.

A statistically significant change ($p<0.05$) was found in the B+S-group P-SES and M-SES tests in the B-SEA – P-SEA comparison. In the P-SES tests, the results changed from B-SEA 27.0 ± 3.5cm to P-SEA 31.7 ± 4.1cm. In the M-SES tests, the results changed from B-SEA 30.8 ± 3.4cm to P-SEA 32.2 ± 3.7cm. There was also a significant change in P-SES ($p=0.006$) and M-SES-jump ($p=0.037$) results in M-SEA – P-SEA measurements. There was also a statistically significant difference between the

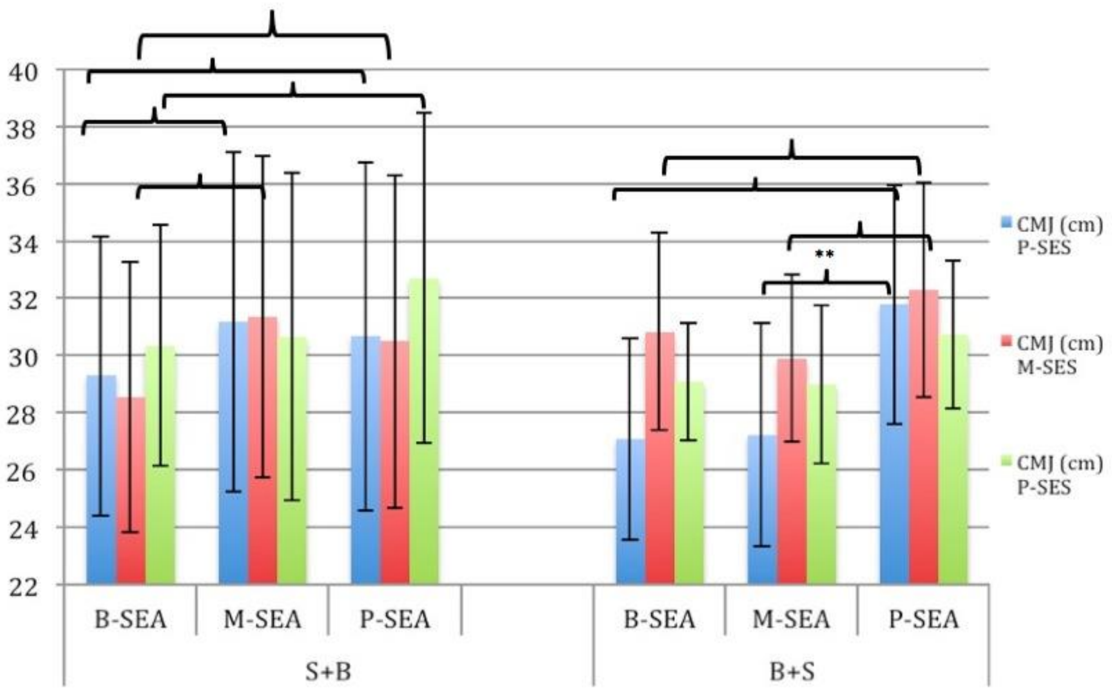


Figure 4. Acute measurements, counter movement jump. Lines over bars indicate statistically significant ($p<0.05$) change. * over bars indicate $p<0.01$ change.

S+B- and B+S-groups P-SES jump results in the B-SEA -measurements (p=0.016). This difference could not be found in the later measurements.

9.3.2 Isometric leg-press

There were statistically significant changes in B+S-group B-SEA - P-SEA values in the B-SES and M-SES -MVC measurements (Figure 5). In B-SES the results changed from B-SEA 229.9 ± 57.4kg to P-SEA 262.3 ± 43.2kg. In M-SES, the results changed from B-SEA 232.2 ± 45.2kg to P-SEA 249.5 ± 47.3kg. Also, there was a significant change in B-SES MVC measurement in M-SEA – P-SEA comparison (p=0.005). There were no statistically significant ($p<0.05$) changes in the S+B-group acute isometric leg-press results.

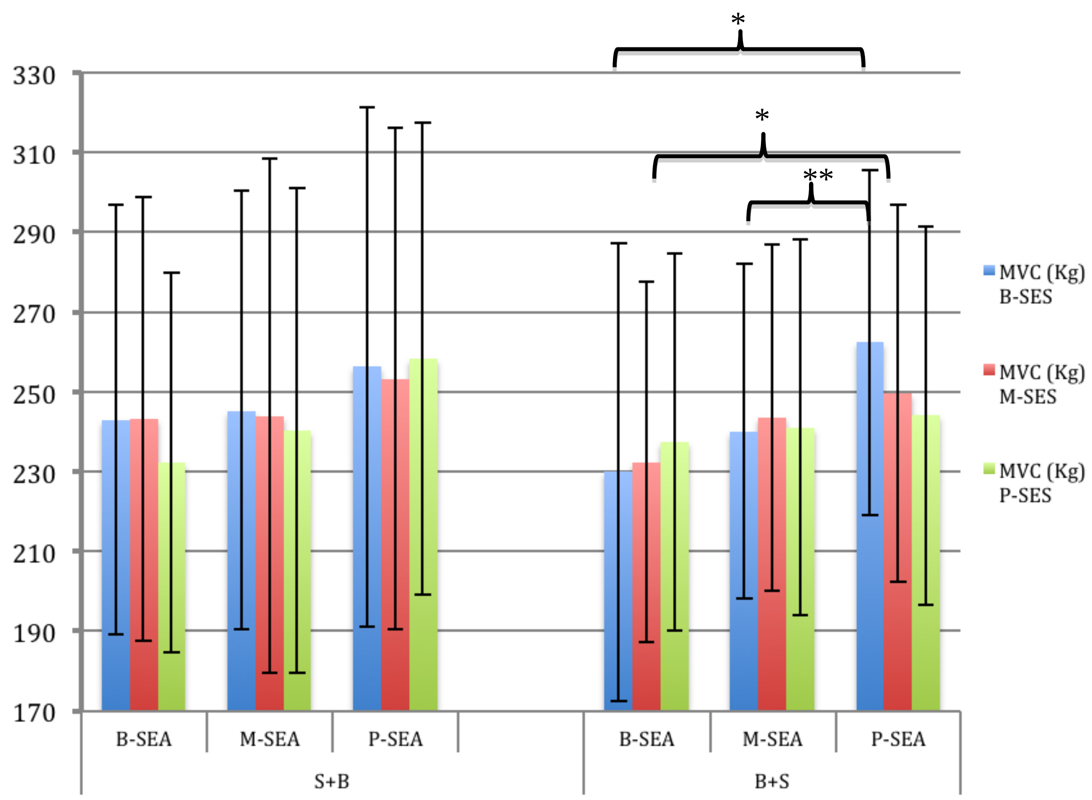


Figure 5. Acute isometric leg press (MVC) measurements in the S+B and B+S groups. *=Statistically significant (p<0.05) change. **= p<0.01 change.

9.4 Laboratory tests

There was a significant change in the B+S-group average force (N) values in 500-1500ms (p=0.037) from that of B-SEA 2157 ± 622N to P-SEA 2451 ± 526N (Figure 6). Also a significant change was found on average force 0-500N and 500-1500N M-SEA – P-SEA values, 0-500N (M-SEA 1598 ± 333 N to P-SEA 1881 ± 440 N) and 500-1500N (M-SEA 2160 ± 384 N to P-SEA 2470 ± 513 N). Also 0-500ms approached a statistically significant change (p=0.089). There was a significant change in the B+S-group Max Force (peak max) M-SEA – P-SEA values (M-SEA 2228 ± 375 N to P-SEA 2530 ± 524 N). The B+S-group Max Force (peak max) approached a statistically significant change in the B-SEA – P-SEA comparison. (p=0.066). There were no statistically significant changes in S+B-group laboratory tests.

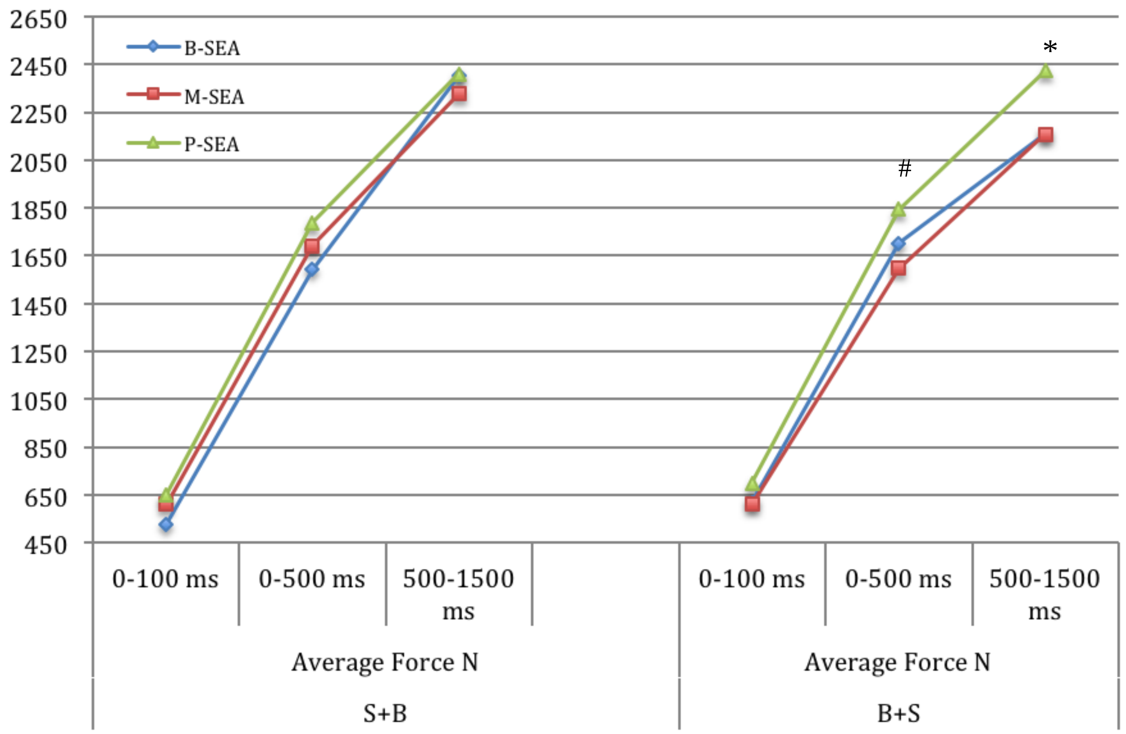


Figure 6. Average force (N) measurements. *=Statistically significant change (p<0.05) B-SEA – P-SEA. #=Statistically significant change M-SEA – P-SEA.

Table 8. Force Production 50% (ms), Peak Max Force (N) and RFD-Max N/s (10ms) results. *= Statistically significant difference between groups (p<0.05).

	Force Production 50% (ms)				Peak Max Force (N)				RFD-Max N/s (10ms)			
	S+B		B+S		S+B		B+S		S+B		B+S	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Pre	127.8*	46.5	93.1*	22.6	2538	722	2306	555	13492	5498	16980	4100
Mid	109.4	30.6	95.3	19.4	2442	618	2228	375	14197	4348	14212	4786
Post	99.0	19.0	93.6	22.2	2474	673	2488	506	15843	5823	16650	5067

There was a statistically significant difference between the groups in force production 50% in the B-SEA -measurement ($p<0.05$). In the S+B-group 127.7 ± 46.5ms and B+S-group 93.1 ± 22.6ms, the statistical difference could not be found in M-SEA or P-SEA measurements (Table 8).

There were no statistically significant changes in RFD-Max (10 ms) values. In the S+B-group the values changed from that of B-SEA 13771 ± 5497 N/s to P-SEA 15843 ± 5823 N/s. B+S-group the values changed from that of B-SEA 16980 ± 4100 N/s to P-SEA 17113 ± 5209 N/s.

There were also no statistically significant changes in peak max force values in neither of the groups. In the S+B-group values changed from that of B-SEA 2537 ± 722N to P-SEA 2474 ± 674N. In the B+S-group the values changed from B-SEA 2306 ± 555N to P-SEA 2488 ± 535N.

9.5 Playing times

There were no statistically significant differences between playing times of the total games played. In the S+B-group subjects played 18.1 ± 5.9 games (19:09 ± 10:23 minutes per game) and in the B+S-group 21.7 ± 6 games (25:53 ± 4:32 minutes per game) during the competitive season.

9.6 Questionnaire

There were no statistically significant differences in regarding the questionnaire answers between the groups. In the S+B- group answers were 6 ± 0.53 for question 1 and 4.5 ± 0.75 for question 2. In the B+S-group 6 ± 1.3 for question 1 and 4.3 ± 1 for question 2.

The questions stated, question 1: “Did you felt that the weight training affected your performance on the court? (1=negatively, 8=Positively). Question 2: “Was the training too light or too hard? (1= too light, 8= too hard)”

10 DISCUSSION

The main finding of this study was that the subjects were able to maintain or improve physical fitness level (both strength and endurance) during the competitive season. Similar kinds of results have been shown also in some recent studies (Gonzalez. et al, Marques. et al 2008) so that players have been able to maintain or improve physical fitness level.

When comparing the acute results in the CMJ and MVC measurements it seems to be that training strength before the sport specific training is more beneficial. In the dynamic movement tests (field tests) it also seems that training before sport specific training might be more beneficial.

The acute tests

The Countermovement jump and MVC tests showed that subjects recovered enough from both sport specific training and resistance training to still perform well in the other one. For the B+S group this showed that the basketball practice was not too strenuous and the resistance training could still be performed optimally, or near the optimal level. For the S+B group, the results showed that resistance training is possible to be performed before the sport specific training without harming the players' performance in basketball practice.

The fact that this kind of basketball practice does not fatigue the players so, that maximum/neural loading and speed training can be done effectively after sport specific training. One of the key things to enable to do this, was the fact that all the heavy leg movements (clean and squat) were performed in the beginning of the resistance training session, thus giving the legs adequate time to recover before the next session. Also, it seems that even though players in the S+B group did arm exercises at the end of the resistance training, according to the questionnaire, it did not affect ball handling or shooting performance within the practice and players did not feel fatigued.

The field-test results were interesting since, with this kind of training, even the high level players were able to maintain or even improve field test performance. This indicates that the resistance training programs were well modified and periodized. In the group comparison, some increases, especially in the clean and squat could be because of improved techniques and on some occasions learning to lift 1RM weights. Usually the goal for competitive season resistance training is to maintain the physical performance of the athletes, as it was also in this study. On the other hand, this might be a wrong approach, since also a lot of improvement was seen during the season. Also Marques et al. (2008) reported improved performance for female volleyball players during the competitive season, so the right approach could be to aim more to improve the performance of the athletes, rather than to maintain the current physical fitness level.

Jump tests and 20

The only statistically significant difference was found in the free-jump results in both groups. The S+B group improved significantly on the B-SEA – M-SEA –measurements, B+S group improved significantly on the M-SEA – P-SEA –measurements, although the improvement for the B+S group was observed after the declined performance in the B-SEA – M-SEA measurements. One of the reasons for no improvement on the CMJ and SJ –tests could be the lack of plyometric/jump training in the resistance training programs. Squat and clean are excellent exercises to increase strength levels of the legs, but the lack of skill to jump and utilize power to the jump was not probably sufficient. The free jump is a lot more sport specific movement, thus done multiple times during the practice and games, which may explain the improvements.

The same kind of conclusion could be done from the 20m sprint results. Even though a lot of running and sprinting was done within the practice and games, the sprints were usually a lot shorter bursts than 20 meters. The results maintained more or less in the same level during the whole competitive season, which is a good thing, but there is room for some improvement. There were no actual sprint-training during the season, which when applied, could lead to improved performance in the 20 meter sprint test.

Also, even though all subjects always had one day off before testing, 20 meter and jump test results may still vary a lot because of individual day to day alertness and fatigue.

Endurance performance

Endurance performance maintained or slightly increased between the B-SEA and P-SEA -measurements in both groups. No actual endurance training was done during the season besides basketball practices and games. Efstratios et al. (2007) proposed the same finding, that basketball practice itself is enough to maintain or improve endurance performance throughout the competitive season. Endurance test used was the beep-test, which some of the players found unpleasant. Still, no lack of motivation completing the test was observed even in the post-measurements, which took place after the season. This might indicate that players learnt during the season, and therefore, took it more as an opportunity to find out their own performance level, rather than an unpleasant task to be completed.

Anthropometrics

There were almost no differences between the B-SEA and P-SEA -measurements in group level. Only marginal SMM (skeletal muscle mass) loss or gains took place during the season in both groups, which indicates also, that this kind of training (only 4 weeks of training in January emphasizing hypertrophic training) is enough to at least maintain muscle mass. If players would have followed a certain diet, the result might have been different and we could have even observed some gains in SMM.

Even though no organized nutritional information was provided (lectures or so) to the players, they all received some information about nutrition every now and then. Also they were, encouraged to ask about nutrition from the coaches if any questions arose. Also, high protein intake was in the topics of every nutrition conversation.

Laboratory tests

In the laboratory tests a slight trend was observed, so that the S+B group baseline level was lower than B+S groups' levels (in force production 50% the group difference was statistically significant) in the B-SEA -measurements. What happened during the competitive season was, that the B+S group held it's higher performance level, and in the meantime the S+B group was able to improve performance near to the B+S performance levels.

In the peak max force –measurements, a bit different phenomenon was observed. The S+B started again with a lower baseline level, but improved performance throughout the study (but no statistically significant differences). The B+S group started with a higher baseline level in the B-SEA -measurements only to decrease performance in the M-SEA -measurements more or less to the same level as the S+B group. On the M-SEA – P-SEA period of the study both groups improved, B+S slightly more reaching near the baseline level. S+B improved throughout the study but not quite reaching B+S groups' performance level. The decreased performance of the B+S in the M-SEA -measurements could be explained with fatigue on players in that group. Even though there were always at least one day off before testing, this might not have been enough for all subjects resulting decreasing performance. Otherwise both force production and peak max force behaved similarly throughout the study, with the only exception of the B+S groups' M-SEA -measurements.

The effect of time of day

The time of day was not fully controlled during the present laboratory measurements. The subjects were informed to arrive to the laboratory measurements at the same time in all (pre, mid and post) measurements. The time of day was not controlled, and the subjects performed the measurements from morning to afternoon. Majority of subjects arrived in all three measurements on the same time of day, but some scheduling conflicts appeared and some subjects performed the laboratory tests on different time of day. This might explain some of the poor performance in the jump and bilateral isometric leg extension tests comparing to the acute testing. The acute measurements were always performed between 4pm and 6pm when majority of subjects performed the laboratory measurements between 8 am and 11 am.

Limitations of the present study and future suggestions

In this study, all subjects performed the same resistance training program. This is not ideal, since a team is composed of group of individuals and, therefore, a more specified approach towards RT programs is needed. The RT programs in this study were more built for the high performance athletes, and even though everyone improved, at least in some tests, there were a lot of individual needs that were not met. Also, plyometrics/jump training and sprinting should be added to the in-season training programs.

Training load and playing times should be also monitored more closely. Even though a player has two games within a week, but does not play more than 15minutes combined, she probably should do both RT exercises. Also, extra rest for players with high playing times should be considered.

The time of day should be observed and recorded. The tests measuring explosive power should not be done early in the morning, or if done it requires a proper warm up. Although it was impossible for this study (lack of pro players) to have the subjects come to the laboratory two times a day (anthropometrics in the morning, laboratory measurements in the afternoon), this would be an ideal situation.

A third group doing the resistance training in the morning could be added for the study design. This way we could possibly see the differences if this kind of training is much more beneficial for the players. The lack of pro-players and the small number off subjects did not allow this kind of study design at the moment.

CONCLUSION

In this study, both groups were able to maintain or improve their physical fitness levels. For semi-pro teams this provides valuable information, since with this kind of sport specific training the resistance could be done either before or after sport specific training. Also, this study showed that an in-season resistance training program could be planned towards improving players' physical fitness level rather than just to maintain performance.

A more individual approach for resistance training is needed in team sports, and monitoring the players training loads and playing times is important to achieve best results. Also, plyometrics/jump training and sprinting should be included in the competitive season training programs. Basketball practice seems to be able to maintain these two attributes, but not enough to improve them.

The testing battery used in the present study seems to very suitable for monitoring changes in players physical fitness levels during competitive season. The tests were not too strenuous and most players were more motivated towards resistance training when testing occurred. Also, contact mat –tests and sprinting tests could be used more frequently as they provide very good exercise at the same time as the players are being tested, in addition, information about players' fatigue levels would also be obtained at the same time.

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12 APPENDIXES

Appendix 1

October - December 2011.

Exercise	Sets x Reps x Weight	Recovery
Squat	3-4 x 4 x 80%	3-4min
Clean	3-4 x 3-5 x 40-50%	3-4min
Bench press with dumbells	3 x 10-12 x 60%	2-3min
Push press with dumbells	3 x 10-12 x 60%	2-3min
One legged box squat	3 x 10per leg	2-3min
Cable triceps extension	3 x 12 x max weigth	1-2min

Exercise	Sets x Reps x Weight	Recovery
Lunge	3 x 6+6 x 40%	2-3min
Ab-roll	3 x 10 x bodyweight	1-3min
Back extension	3 x 12 x bodyweight	1-3min
Inverted row	3 x 10 x bodyweight	2-3min
Cable pulldown/pull-up	3 x 10-12 x 60% / 3 x max	2-3min
Bent over row with bar	2 x 10 x 60%	2-3min

Appendix 2

January 2012.

Exercise	Sets x Reps x Weight	Recovery
Squat	3 x 10 x 60-80%	3-4min
Clean	5 x 5 x 50-80%	3-4min
Bench press	3 x 10-12 x 60-80%	2-3min
Speed jerk	3 x 8 x 40%	3-4min
One legged box squat	3 x 10per leg x 0-5kg	2-3min

Exercise	Sets x Reps x Weight	Recovery
Lunge	3 x 6+6 x 40%	2-3min
Inverted row	3 x 10 x bodyweight	2-3min
Bent over row with bar	3 x 10 x 60-80%	2-3min
Ab-roll/push up-walk	3 x 10 x bodyweight	1-3min
Back extension	3 x 12 x bodyweight	1-3min
Bicep curl+push press	3 x 10-12 x 60-80%	1-3min

Appendix 3

February - May 2012

Exercise	Sets x Reps x Weight	Recovery
Squat	3 x 3-4 x 70-80%	3-4min
Clean	3 x 5 / 4 x 3 / 2 x 5 + 2 x 3 Weight: ~80%, but always leave 1-2 reps into ”reserve”.	3-4min
Hurdle jump	3-4 x 3-5 hurdles	Walking recovery during sets, 3mins between sets
Bench press	3 x 8 x 70-80%	3-4min
One legged deadlift with dumbells	2 x 8+8	2-3min

Exercise	Sets x Reps x Weight	Recovery
Lunge	3 x 6+6 x 40%	2-3min
Inverted row	3 x 10 x bodyweight	2-3min
Bench jump	3 x 5	2-3min
Back extension	3 x 12 x bodyweight + 5-10kg	1-2min
Bicep curl+push press	3 x 8 x 60-80%	2-3min
Elevated cable row	3 x 10 x 60-80%	2-3min