The Effects of an 8-Week, Pre-Season Training Program on Vertical Jump, Agility and Anaerobic Power in Elite Female Basketball Players

by

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Abstract

The objectives of this study were to evaluate the effectiveness of an eight-week training program by comparing changes in four performance indicators: vertical jump, peak power, agility and anaerobic power. An additional objective was to monitor the adaptive process of each subject in the treatment group by quantifying the training stimulus and measuring these adaptation indicators: fatigue, stress, sleep quality and DOMS, via a daily training log. The treatment group, (n= 10) completed an eight-week pre-season plan, which emphasized agility, explosive power and anaerobic conditioning and followed an undulating periodization model. The control group, a college level team, (n = 9) participated in regular practice sessions only. Three repeated measurements were taken on the treatment group (baseline, at week 5 and at week 9) and two measurements were taken (baseline and week 9) on the control group. Tests administered to both groups were a vertical jump test, a T-test and an anaerobic speed test. A 2 x 4 MANOVA was conducted to measure performance changes over time with the treatment group. Statistical significance was set at $\alpha <. 05$. Although statistical significance was only detected when comparing week 5 to week 9 (p=.041) the descriptive results showed the athlete's in the treatment group improved in all four performance indicators,. Follow-up univariate analysis confirmed that the agility scores were significantly better at week 9 (p=.009). It was also found that the once individual athlete's training logs were quantified, those who documented a maladaptive pattern also did not show improvements in performance. A multivariate two sample t-test was also performed to assess differences between the treatment group and the control group. No significance was found (p=.308). This study indicates that, although both groups demonstrated

improvements in all four performance indicators, the treatment group's improvement is more noteworthy because they were initially closer to their biological ceiling. Also, the training log in combination with periodic performance testing, supports the hypothesis that these are excellent methods of monitoring an athlete's adaptive capacity and can provide rationale for declines in physical performance.

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List of Abbreviations

ATP	Adenosine Triphosphate
CG	Control group
CS	Control group subject
cm	Centimeter
DOMS	Delayed onset of muscle soreness
kg	Kilogram
OTS	Overtraining syndrome
PCr	Phosphocreatine
Pi	Inorganic phosphate
Reps	Repetitions
RFD	Rate of force development
RM	Repetition maximum
RPE	Rating of perceived effort
SSC	Stretch shortening cycle
SS	Superset
Tech	Technical sport practice
Tach	Tactical sport practice
TG	Treatment Group
TS	Treatment group subject
VO_{2max}	Maximal Oxygen Consumption

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Introduction

Improving the identified physical parameters necessary for elite sport performance is a multi-faceted undertaking. The specific physiological adaptations, which explain training induced changes in team-sport athletes, have yet to be examined comprehensively (Fleck, 1999). Most periodized training studies to date have measured the physiological and biochemical responses of the human subject to uni-faceted endurance training programs and have paid less attention to the extent to which human exercise performance is altered in non-endurance programs. These types of programs often involve technical and tactical sport practice as well as strength, speed, endurance and movement-based performance parameters. Observation of performance results and their relationship to training is of particular interest to the athlete who has been training and competing at a high level prior to the addition of, or more specific, training program.

The majority of research studies, examining the effectiveness of periodized training, have focused on direct strength and power gains via the manipulation of intensity and volume alone, rather than the effect the program has on sport performance. Furthermore, most profile studies have tended to focus on performance of swimming, cycling, wrestling, skiing and running, which are all individual sports (Lamonte, 1999), These individual sports have simply been profiled more frequently due to the ease of evaluating these athletes in the lab setting (Lamonte, 1999). It is clear that more research is needed to evaluate training responses of team sport athlete populations. This research has meaningful application at the coaching level and will enhance results on the performance level of competitive basketball athletes

Periodization research has shown that basketball athletes benefit greatly from a strength and conditioning program (Groves & Gale, 1993). Normative data and standardized testing protocols have also become available to identify the specific physical requirements of basketball, and more recently, physical and physiological profiles of individual athletes have been reported (Lamonte, 1999). Recently, more studies have been conducted on the female athlete's response to a variety of periodized training protocols from traditional models to undulating models (Dudley & Fleck, 1987). Past training studies conducted on female basketball athletes has been focused on collective team profiles versus individual physical profiles and individual adaptation to the training program (Lamonte, 1999), thus illustrating the need to evaluate the training response for each athlete involved in a team sport.

The period prior to the official starting date of the competitive season is termed the pre-season conditioning period. During this period, which typically lasts 8 – 10 weeks, the goal is to achieve maximal physical performance. The application of undulating periodization, where the resistance (intensity) and other variables are varied daily or weekly is deemed to be most effective in enhancing physical performance of basketball athletes (Stone, 1997). Its primary purpose is to prevent overtraining and maximize training frequency and total work accomplished (Stone et al., 1997, Baechle 2000). Undulating periodizaton allows for maintenance of strength and improvements in power (Kraemer 1997, Poloquin, 1988, Harris et al. 1996), which were the goals of this the pre-season program.

The predominant performance requirement for success in a large number of athletic skills is explosive power (Newton & Kraemer, 1994). Therefore, the main emphasis points for a basketball pre-season program should be on improving explosive power, sport specific agility and anaerobic power (Marsit, 1994). A combined program of plyometric training and resistance training produces optimal improvements in jump performance (Ebben, 2002; Hedrick, 1996). Many investigations have shown that the maximal rate of force development is a very significant factor in explosive performance (Kraemer & Newton, 1994). For years, information from the field of sport science has led to a practical interpretation at the coaching level that a periodized, progressive, strength-training program incorporating general strength training, stabilization, balance, Olympic lifting, and plyometrics as well as speed and agility drills would achieve optimal explosive performance.

The goal of basketball practice and physical conditioning is to provide a stimulus for the specific adaptations that will result in improved athletic performance. The maintenance or improvement in performance standards is not, however, solely determined by appropriate conditioning. The ability of bodily systems (e.g., neuromuscular system, endocrine system) to recover and regenerate following composite stresses including strenuous physical activity, psychological stress of practice and competition, etc., can also influence physical performance. And of particular importance to force development is the manner in which muscles respond and remodel following exercise stressors. When a player is training, practicing and competing, the dynamic homeostatic balance created between anabolic and catabolic processes within the muscle can ultimately influence muscular force characteristics and, therefore, affect the quality of a player's performance.

It is essential that we study the effects of a training program on performance and adaptation patterns of competitive athletes. The methodology of measuring the effects of a periodized pre-season plan has not been a focus of attention in the literature (Hopkins, 1991). Instead, physiological monitoring has been at the forefront of leading research. Exercise-induced decreases in force production resulting from muscle injury during training have also been researched; what hasn't is a formal model of tracking fatigue and performance variables (Taha & Thomas, 2004). The purpose of formalizing and quantifying adaptation is to systemize training prescription for anaerobic/intermittent team sports (Hopkins, 1991). Also, it is critical to investigate a means of tracking sports injuries and risk factors for overtraining syndrome (Hopkins, 1991).

Overtraining Syndrome can be defined as an imbalance between the training stimulus and recovery. It is a general term used to describe the process of training excessively and the fatigue state and symptoms that may develop as a consequence (Callister et al, 1990). It is characterized by sub-par sport-specific physical performance, accelerated fatigability and subjective symptoms of stress. (Urhausen & Kinderman, 2002) Overtraining is the stimulus; a single consequence may be what is detrimental to an athlete's performance. An imbalance between the overall strain of training and the individual's tolerance of stress over time can lead to overtraining.

Overtraining or maladaptation to a training program is primarily related to sustained high load training, "often coupled with other stressors in the individual's life" (Foster, 1998, p. 1161). Physiological markers that have been documented include chronic fatigue, sleep disorders and chronic muscle soreness and damage. The use of performance measures such as strength, speed and agility, as well as monitoring sleep, stress, and fatigue are also good method of monitoring training stresses (Hoffman, 2000). Hopkins has found (1991, p. 175) in his review that various symptoms of overtraining "can be identified anecdotally". The occurrence of fatigue depends primarily on how the individual athlete responds to the training stimulus, which can be problematic in team sports when the program is developed for the team not the individual (Hoffman, 2000).

The ability to monitor training is critical to the process of evaluating and quantifying a periodized training plan. Endurance athletes have often used training volume, measured in distance as a means of documenting the training load as well as heart rate as a measure of intensity. Evaluating a training session using a type of rating of perceived exertion scale (RPE) has been shown to be a useful and practical tool in correlating the physical demands on the body over time with athletes that could be possibly overtraining (Anderson et al. 2003).

How the muscles respond and remodel following exercise stressors is of particular importance in force development and force characteristics. Delayed onset of muscle soreness (DOMS) is the most commonly used indirect marker of muscle damage in human studies (Byrne, Twist & Eston, 2004). DOMS is usually associated with unfamiliar, high-force muscular work and is precipitated by eccentric actions (Cheung, Hueme & Maxwell, 2003). Training involving excessive eccentric loading will magnify DOMS and increase the level of direct structural damage to the muscle. Logically, the amount of muscle damage does often dictate the level of soreness (Clarkson & Hubal, 2002). However, it is the process of chronic overloading of the musculature and maladaptation that can lead the athlete into a state of overtraining, which can escalate into chronic fatigue and decreased performance.

Since the physical requirements for basketball have been established in the literature, implementation and documentation of specific training, regarding: workloads, periodization and corresponding performance results are needed (Lamonte, 1999). There is also an obvious need for regular training stress and adaptation determinations within the framework of a conditioning program and practice schedule as well (Hartmann and Mester, 1997)

The objectives of this study were to evaluate the effectiveness of the training program by comparing the changes in four performance indicators: vertical jump, peak power, agility and anaerobic power, between athletes following an 8 – week pre-season program and athletes not following the program. An additional objective was to monitor the adaptive process of the treatment group by quantifying both sport practice and training load and as well as these adaptation indicators: fatigue, stress, sleep and muscle soreness.

With the research done in the past on sport performance and periodization, the hypotheses state:

1. The athletes that are following the 8-week structured training program will demonstrate greater improvements in explosive power, anaerobic power and agility versus the control group who are not following any structured training program.
2. The training log used daily by athletes in the treatment group combined with a performance testing session at week 5 will serve as a useful evaluation tool to:
    a. illustrate the degree of adaptation to the 8-week training program, and
    b. explain the results of the four dependent variables for each subject in the treatment group.

Methodology

Subjects

Ten female University of British Columbia varsity basketball players and nine female Langara College control subjects participated in this study. All subjects were between the ages of 18 and 24, with a minimum of 4 years of previous competitive basketball history and no musculoskeletal injuries that prevented them from physical participation during the course of the study. Subjects also had no history of pulmonary, cardiac, vascular, neurological or muscular degenerative diseases or disorders. Ten subjects began the study in the control group, but one subject quit the team, reducing that group to nine eligible subjects.

The groups were matched on these descriptive variables: chronological age, VO_{2max} and year of eligibility. Both subject groups are representative of female, high intensity, intermittent, impact, and team sport athletes. Informed consent was obtained in writing and subjects were free to withdraw from the study at any time. Study procedures were approved by the Clinical research Ethics Board of the University of British Columbia.

Research Design

The treatment group completed an 8-week pre-season program that combined sport practice, games and strength and conditioning sessions. Tactical and technical training, during team practices, were held five to six times per week and strength and conditioning sessions were held five times per week. Plyometrics and agility, resistance and complex training and anaerobic conditioning were all part of the strength and conditioning program. The training schedule and number of each type of training session is found in the appendix section. The control group engaged in regular practice sessions and games five times per week and did not follow a strength and conditioning program.

Experimental Protocol

Subjects in the treatment group were required to report to the testing on three, separate occasions: baseline (week one), week five and week nine. Field tests were conducted on the basketball court on three separate occasions the day prior to the laboratory tests. Subjects in the control group were tested on two occasions: baseline and week nine. Laboratory tests included each subject's sport history, year of eligibility, birthdate and anthropometry measures (height and weight). The Cunningham and Faulkner test of anaerobic power (AST), and a two-foot vertical jump were also administered in the laboratory. The field tests conducted on the basketball court included the T-Test, a measure of agility, and the Leger-Boucher Beep Test, a measure of aerobic power. The Leger-Boucher Beep test was only conducted at week one to match both subject groups on aerobic fitness and was not considered a dependent variable in this design. Subjects in the control group were required to report to the lab on two separate occasions. The same tests were conducted for this group at baseline and week nine.

Day One: Laboratory Tests

The subject's height without shoes was determined to the nearest .1 cm. The subject's weight, wearing shorts and a t-shirt, was recorded to the nearest .1 kg with the use of a calibrated electronic scale. Chronologial age, birthdate, number of years of playing experience and year of eligibility was recorded at the start of the study.

Lower Body Peak Power

Peak power was evaluated via the assessment of the vertical jump. Maximal vertical jump height was measured using a Vertec vertical jump measurement device (Sports Imports, Columbus, OH). Prior to testing, the standing vertical reach for each subject was determined by raising her right arm. Care was taken to make sure the standing reach was accurately determined with regard to limb stretch. Subjects' peak power was assessed by a vertical jump that involved a one step approach; a countermovement and a two-leg take off. This protocol, involving a countermovement phase, measures dynamic functional power by incorporating the stretch-shortening cycle, which is specific to basketball (Gleddie, 1994). Use of the countermovement jump versus a squat jump allows the muscle to act eccentrically to slow the body and initiate the upward movement. Athletes were instructed on how to perform the test for a best score and were told to bend their knees quickly, fully extend all joints of the lower body and look up at the jumping target. Subjects were also permitted to swing their arms in attempt to make it more specific to the jumping pattern involved in basketball. Subjects were also given 3 trials to jump for maximum height, with 2 minutes rest separating trials. Only the highest jump of the 3 trials was recorded. Trials with noticeable faults were repeated. Determination of maximal vertical jump height was calculated based on the difference between maximal single arm reach and the highest score of the 3 trials. Calculations to determine peak power were made using the D.L. Johnson equation:

Peak power = 78.47 x vertical jump height (cm) + 60.57 x mass (kg) – 15.31 x height (cm) – 1308

(MacDougall, Wenger & Green, 1991).

Anaerobic Power

Running performance and anaerobic power was assessed by the Cunningham and Faulkner or anaerobic speed test (AST). After a standardized warm up on the treadmill, of 5 minutes at 6.0 miles per hour, subjects performed the run at 7.5 mph (3.3528 m/s) at a 20% grade until volitional fatigue. Fatigue was defined as an inability of the subject to continue at the set treadmill speed. Time (seconds) to fatigue was used as the performance index. One trial was performed on this test but subjects were familiarized with both running on a treadmill and exiting a moving treadmill upon completion. Subjects were asked to avoid food less than two hours prior to testing. The test-retest reliability of the AST has been documented by MacDougall ($r = 0.76–0.91$) (1991).

Day Two: Field Tests

All testing, for both groups, was conducted indoors in the university and college gymnasiums on the basketball court to maintain a consistent surface and to eliminate confounding variables in an outdoor environment. During the test session, all subjects were allowed to perform an individual warm-up, which consisted of dynamic movement patterns and light shooting drills for approximately fifteen minutes. Static stretching was not permitted prior to these tests. The order of the tests and the order of the subjects were consistent for all tests and for each testing session. The field testing began with the T-Test for agility and was following by the Leger-Boucher Beep Test. During baseline testing, both tests were administered. Only the T-Test was administered during week 5 for the treatment group and week 9 for both groups. The Leger-Boucher Beep Test was not re-administered. Subjects were asked to avoid food less than two hours prior to testing.

Agility

Agility, leg power and leg speed are believed to be important physical components necessary for successful performance. (Pauole, Madole, Garhammer, LaCourse & Rozenek, 2000) Agility was measured using a T-Test. The test was administered using the protocol outlined by Semenick (pp. 36, 1990). Subjects began with both feet at point A. At their own initiative, they sprinted forward to cone B (9.14m), where they decelerated and changes their movement pattern to a shuffle and made their way to the left to cone C (4.57 m). The midline of the body had to line up with cone C and testing volunteers ensured accuracy here. They did not have to touch the cone. Next, they shuffled to cone D (9.14 m), where they lined up the midline of their body again. Finally they shuffled to the left again, back to cone B and ran backwards past cone A to finish the test. Subjects were instructed to stay low on the shuffles, to push with the outside foot and not let their feet touch together on each shuffle.

This test is described as a measure of four-directional agility and body control that evaluates the ability to change directions rapidly while maintaining balance without loss of speed (Pauole, Madole, Garhammer, Lacourse & Rozenek, 2000). There is no published test, re-test data available to date. It does, however, appear to be a reliable and valid measure of leg speed and secondarily of leg power and agility (Pauole et al., 2000) and of value to conditioning specialists who wish to assess improvement in anaerobic performance as a result of participating in a training program. This test has been chosen based on the specificity principle and the performance criteria identified for basketball. The T-test was administered three times with two minutes rest between attempts. The best score, which is the lowest time recorded to the nearest one hundredth of a second was recorded and the statistical analysis was performed on that score.

Aerobic Power

Aerobic power was assessed using the Leger-Boucher Beep Test during the baseline testing session for the purpose of matching the two groups on aerobic fitness. The subjects ran continuously between two lines 20 meters apart in time to recorded beeps. The time between recorded beeps decrease with each minute (level). The athlete's score is the level and number of shuttles reached before they were unable to keep up with the tape recording. This score was converted to a VO_{2max} predicted score (Leger & Gadoury, 1989). There are published VO_{2max} score equivalents for each level reached and the correlation to actual VO_{2max} scores is high ($r=.73$, $p<.001$) (Leger & Lambert, 1982).

The Strength and Conditioning Program

The eight-week strength and conditioning program shows a general increase in total load by week 4, where the athletes were predicted to overreach. After week 5, the program begins to taper with the aim to restore the athletes for competition.

Resistance Training Program

Resistance training sessions were held for the treatment group on Mondays (7 work-outs), Thursdays (8 work-outs) and a Saturdays (4 work-outs). Monday work-outs consisted of Olympic Lifts, multi-joint exercises and stability training for the core musculature. The work-out intensity was 85% of 1RM, or 100% of 4-6RM. Thursday's resistance training session combined with plyometric training, using a method called complex training. The work-out intensity was lower than Monday with 70% of 1RM,or 100% of 8-10 1RM. Saturday's session included upper body power exercises, allowing the legs some recovery. The intensity was the lightest of the week, with 50% 1RM, or 100% of 8-12 RM. Over the eight-week period, volume was decreased and intensity was increased, allowing for a taper prior to the competitive season. Each athlete recorded completed work-outs in their training log and also listed the amount of weight lifted per exercise and the amount of repetition completed on each set. Consult the appendix section for the resistance training program and daily variation of volume and intensity.

Exercise order was carefully considered with power exercises performed at the beginning of the work-out. Because power exercises require the highest level of skill to perform, fatigue from other exercises can impact their effectiveness. Single-joint, supplementary and stability exercises were placed at the end of the training session, or paired with an antagonist muscle group exercise to maximize time efficiency. The athletes were also prescribed a dynamic warm-up, involving either gross motor movements with light weights, prior to monday's work-out, or a sequence of joint activation exercises (prior to the Thursday lift) to prepare them physically for the work-out. Thursday's lift, because of the limited rest between complexes was followed by a 20 minute moderate cycle with the aim to maximize muscle recovery from the training session.

Plyometrics Training Program

All subjects in the treatment group participated in a plyometric training program, every Tuesday for 6 sessions. Jump training exercises were incorporated twice per week, once on their own prior to movement and agility training drills and once in combination with resistance training exercises as a complex. Explosive jumping, quickness (timed jumping and re-jumping), and power-endurance were stressed during the plyometric work-outs. Training sessions used a regulation sized basketball court with a wood spring floor surface. The exercises progressively increased in volume, as measured by the number of foot contacts, and intensity, as measured by the amplitude of the jumps, throughout the eight-week training camp. Week one, the athletes completed 140 foot contacts, week 2, they completed 180 foot contacts, week 3, 220 foot contacts, week 4, 250 foot contacts. During week 5, the athletes were re-tested and only completed 80 foot contacts. Week 6, they finished the pre-season program with 220 contacts, the same load a week 3. Plyometric training tapered at week seven with the aim to restore the subjects for the start of their competitive season.

Subjects were coached to achieve maximum height on power skips and vertical jumps and minimal ground contact time on lateral hops and bounding exercises. They were also instructed on proper landing technique, a short amortization phase, coordination of the arms and maintaining upright posture during the sessions. Rest was passive and approximately one minute between sets. A list of the plyometric drills performed is outlined in the appendix section.

During the complex training session on thursdays, subjects were instructed to perform a plyometic exercise immediately following a heavy resistance exercise as outlined in their program. Then they were to rest passively between sets.

The control group did not partake in a regimented resistive training or plyometrics program. The training program for the control group consisted of regular basketball practices and games.

Agility Training

Agility training drills were performed once per week on Tuesdays, after plyometrics during the pre-season conditioning period. Drills consisted of movements specific to basketball: lateral shuffles, short forward to backward transitions and change of direction drills. Instructions from the conditioning coach included maintaining a low center of gravity and bent knees when decelerating or accelerating out of tight turns, maintaining a dorsi-flexed foot position on the outside foot and dropping the inside shoulder on all cutting movements, strong and rapid arm drive to propel the body and keeping the eyes focused on the direction of intended movement. Drills progressed from week one to week eight by increasing the complexity of the movement patterns, decreasing the rest period between drills and combining sequences of movement patterns in an unpredictable, or a read and react scenario. The athletes in the treatment group were familiar with the drills prescribed in this section of the conditioning week as they had performed many of them the year before, thus the positive transfer of learning effects was not a threatening confounding variable in this research design.

Anaerobic Power Training Program

Anaerobic conditioning sessions were held on Fridays for 5 consecutive sessions. Anaerobic power was trained with the use of multi-directional sprinting drills without the basketball on a court surface. Athletes began the sessions with a ten-minute dynamic warm-up, incorporating joint range of motion and mobility drills with increasing movement speeds. Drills prescribed on this day of training included: Complete the square, shuffle and jump, line repeats, partner sprints and follow the leader sprints. Each drill is briefly outlined in the appendix section. Generally, three drills were picked for each training session. The team was divided first into partners, then into stations, with two groups of two at each station. Those who were recovering were encouraged to coach those athletes who were performed the drill to maintain a high level of intensity. An element of competition, such as a race, or a score was given to each drill to increase the level of intensity. Six sets of each drill were performed. Weeks one and two, incorporated 6 x 30 second intervals per drill with 90 seconds of passive recovery. Weeks three to five increased the length of the work interval to 6 x 45 seconds with a 45 second rest interval. Following the anaerobic conditioning sessions, the athletes, performed a 10 minute cooldown jog and a static stretch.

Quantifying Sport Practice and the Training Load

Throughout the course of this study, the treatment group was responsible for participating in activities planned by the strength and conditioning coach. In order to document the stresses of practice, games and the conditioning program effectively, measures of intensity, frequency and duration were recorded. Subjects were required to fill out a log (see Appendix) after each training session and basketball practice. The log served as a means of quantifying the training load and the time course of adaptation to training. It was comprised of questions related to the subjects rating of perceived effort (RPE) for that particular practice, game or training session as well as the duration of the session. Intensity was recorded by using a modified Borg RPE scale of 1-10 (CR-10 RPE Scale) at the end of each session. This scale has been validated against objective markers of exercise intensity such as heart rate and blood lactate levels (Foster et al, 2001). It has been found that heart rate is not an accurate means of assessing training load in intermittent activity (Foster et al., 2001). Even the well-known TRIMP method could not be used in this case as heart rate is used in that method as a means of measuring intensity. The RPE method has been shown to be a "more reliable and useful tool" (Day, McGuigan, Brice & Foster, pp. 357, 2004). Training load was calculated later by multiplying the session RPE by the duration (minutes) of the session. Training load for each day for both strength and conditioning sessions and practice sessions were quantified and plotted with the corresponding weeks of training. Both the conditioning coach and the sport coach also rated each training session or practice on the CR-10 RPE scale as well as the duration to further validate the athlete's ratings against the training and practice session prescription.

Quantifying Adaptation to the Training Program

A formal meeting was held prior to the data collection period with the treatment group to deliver the athlete's training logbook and explain how to complete it accurately. During the eight-week treatment period, each subject was instructed to rate fatigue, stress and sleep in their log book. Also, on the log sheets provided for each subject in the treatment group, a visual analogue scale (VAS) was presented with a 10 cm baseline, rating DOMS from no pain to unbearable pain in the lower body only. Each subject was instructed to draw a vertical line perpendicular to this line, indicating the level of muscle soreness in their lower body when they were performing normal daily activities or practicing basketball. The line was measured during the data collection by the investigator with a standard metric ruler to the nearest .1 cm and recorded daily for each subject (see appendix for sample log). Fatigue, stress and sleep quality were quantified using the numeric rating scale of 1-10. The value for each adaptation indicator were added up to give a weekly score of fatigue, stress, sleep quality and DOMS. Injuries, both chronic and acute, and the use of NSAIDs were also documented anecdotally on a daily basis.

Regular attendance was taken during the strength and conditioning sessions. Subjects also recorded the completion of each weight-lifting and complex training session in their training logs, so adherence to the program could be monitored closely. Any modifications to the program due to injuries were also recorded.

Statistical Analysis

Means and standard deviations were calculated for all variables. An independent T-test was used to determine differences between the control and the treatment groups in descriptive data and baseline performance data.

Percent change from baseline to week 5 and to week 9 for both groups and individual subjects was also calculated to assess changes in performance indicators. A 2 x 4 MANOVA was conducted to analyse the pair-wise differences in scores of each dependent variable (performance indicator) between the three testing points within the treatment group. The alpha level was set at .05.

Multivariate analyses (Pillai's Trace, Wilks' Lambda, Hotelling's Trace and Roy's Largest Root) also assessed significance in results from each testing point between all four dependent variables between the treatment group and the control group to see if there were differences in the two groups. A follow-up univariate analysis was also conducted to determine which dependent variable contributed most to the difference between the two groups. The SPSS/PC statistical package was utilized.

The independent variables were the strength and conditioning program and the groups, whereas the dependent variables were the four performance indicators: vertical jump height, peak power, agility and anaerobic power. Finally, a logarithm for each treatment group subject was devised to monitor any trends in adaptation to the eight-week treatment period as well as perceived training loads during that time.

Results

Descriptive Characteristics

The subject groups involved in this study were matched on $V0_{2max}$ (treatment average = 46.8 ml/kg/min ± 3.75 ml/kg/min, control average = 47.33 ± 5.10 ml/kg/min, *p*=.553), year of eligibility (treatment average = 2.22 ± .67 and control average = 1.78 ± .83) and chronological age (treatment average = 19.3 ±1.08 years and control average = 18.9 ± 1.05 years, *p*=.230) The groups were also statistically similar on mean height (treatment group = 178.83 ± 6.25cm and control group = 173.89 ± 6.58 cm, *p*=.059), Additionally, each member of each group self-reported more than four years of playing experience prior to the study.

Independent T-tests revealed the treatment group and the control group differed statistically on the descriptive variables: mean weight (treatment group = 75.29 ± 9.85 kg and control group 63.35 ± 10.8 kg, *p*=.017) and physical training experience. The treatment group had been following a strength and conditioning program prior to the onset of the treatment period whereas the control group did not. Also, the treatment group competes at a more elite level than the control group. See Table 1 for the descriptive data for each subject within both groups.

The treatment group is also statistically different from the control group at baseline in three of the four dependent variables: vertical jump (*p*= .027), peak power (*p*=.002), and agility (*p*=.002). Baseline anaerobic power scores were statistically similar between groups (*p*=.321). Baseline values for both groups are shown in Table 2.

Table 1. Individual descriptive data of the treatment subjects and control subjects

	Height (cm)	Weight (kg)	Age (years)	Yr of Elig	VO_{2max} ml/kg/min
TS1	175	72.3	19	2	53
TS2	184	97.3	20	3	43
TS3	174	68.4	19	2	48
TS4	182.5	63.3	20	3	45
TS5	170.2	71	18	2	45
TS6	183	66.8	18	2	50
TS7	173.5	80.5	20	2	47
TS8	186.3	76.8	19	1	43
TS9	181	81.2	21	3	47
TS10	189	81.4	21	3	40
TG Mean ± SD	178.83 ± 6.25	75.29 ± 9.85	19.33 ±1.08	2.22 ± .67	46.78 ± 3.75
CS1	158	47	19	2	44
CS2	174.5	56.2	20	3	53
CS3	174	56.3	19	3	55
CS4	172.2	68.64	20	1	48
CS5	180.3	58.73	20	1	52
CS6	172.7	57	18	1	44
CS7	177	72.2	17	1	40
CS8	179.2	73.8	18	2	43
CS9	177.1	80.3	19	2	47
CG Mean ± SD	173.89 ± 6.58	63.35 ± 10.8	18.9 ± 1.05	1.78 ±.83	47.33 ± 5.10

* group data presented as mean ± standard deviation; TS, treatment subjects, CS, control subjects, there are no statistically significant differences between groups in height, p=.059; age, p=.230 & VO_{2max}, p=.553

Table 2 : Baseline (Week 1) individual scores from the treatment and control subjects for each performance indicator (dv)

Indicator:	Vertical Jump (cm)	Peak Power (watts)	T-Test (seconds)	AST (seconds)
TS1	41.91	3680.64	9.50	54.92
TS2	48.26	5693.17	10.34	36.22
TS3	41.91	3459.73	10.00	32.44
TS4	50.80	3718.28	10.06	42.19
TS5	40.64	3575.73	9.91	28.34
TS6	54.61	4221.59	10.03	52.41
TS7	49.53	4795.87	9.44	39.75
TS8	49.53	4375.79	9.47	37.97
TS9	48.26	4626.14	10.00	41.65
TS10	39.37	3818.17	10.22	26.72
TG Mean ± SD	47.27 ± 4.87	4238.55 ± 662.15	9.86 ± .30	40.63 ± 8.73
CS1	48.26	2906.77	9.78	45.00
CS2	34.29	2115.18	10.60	39.75
CS3	48.26	3225.11	10.16	44.09
CS4	41.91	3501.82	10.62	32.06
CS5	38.10	2478.59	10.78	37.63
CS6	35.56	2290.85	10.79	22.78
CS7	44.45	3843.28	10.47	35.00
CS8	31.75	2909.94	10.88	27.88
CS9	40.64	4034.92	10.19	33.75
CG Mean ± SD	40.36 ± 5.61	3034.05 ± 673.672	10.47 ± .34	35.33 ± 6.84

* group data presented as mean ± standard deviation. TS, treatment subjects, CS, control subjects, dv, dependent variable

The treatment group was measured on each performance indicator at week 5 during the eight-week training period. During this time, the athletes had completed an overloading phase where it was theorized that there may be a decrease in performance during this testing period and higher ratings of perceived exertion during conditioning sessions and practices. Table 3 shows the results from the testing session at week 5. At week 9 both groups were retested on all four, performance indicators, and after the treatment group unloaded and tapered their training program. Results for each subject, in both groups are shown on Table 4.

Table 3. Week 5 individual scores from the treatment subjects only (TS) for each performance indicator following an overload

Indicator:	Vertical Jump (cm)	Peak Power (watts)	T-Test (seconds)	AST (seconds)
TS1	48.26	4178.92	10.00	57.12
TS2	47.00	5594.30	10.28	39.84
TS3	48.26	3958.01	9.90	28.09
TS4	47.00	3420.10	10.29	47.85
TS5	40.64	3575.73	9.94	27.10
TS6	54.61	4221.59	10.00	52.84
TS7	49.50	4178.92	9.56	44.78
TS8	48.26	4502.59	9.69	44.50
TS9	45.72	4426.82	10.10	42.00
TS10	40.64	3917.83	10.50	30.47
TG Mean ± SD	46.99 ± 4.10	4197.48 ± 598.56	9.97 ± .28	41.46 ± 10.24

* group data presented as mean ± standard deviation

Table 4. Week 9 Individual Scores from the Treatment (TS) and Control Subjects (CS) for each Performance Indicator

Indicator:	Vertical Jump (cm)	Peak Power (watts)	T-Test (seconds)	AST (seconds)
TS1	45.72	3979.61	9.53	52.16
TS2	49.50	5788.69	10.25	36.48
TS3	49.50	4055.31	9.67	36.10
TS4	52.07	3817.94	10.19	45.60
TS5	40.64	3575.73	9.91	29.50
TS6	60.96	4719.88	9.71	58.59
TS7	50.80	4897.88	9.36	49.10
TS8	52.07	4577.46	9.73	54.00
TS9	44.45	4327.17	9.61	40.16
TS10	40.64	3917.83	10.39	34.20
TG Mean ± SD	48.64 ± 5.79	4352.15 ± 589.88	9.84 ± .32	43.59 ± 9.20
CS1	48.26	2906.77	9.74	50.00
CS2	41.91	2713.17	10.07	43.21
CS3	45.72	3025.80	10.13	45.35
CS4	44.45	3701.13	10.79	35.87
CS5	41.91	2777.56	11.03	36.51
CS6	41.91	2789.13	10.96	26.60
CS7	50.80	4341.56	10.52	38.66
CS8	36.83	3308.56	10.50	30.90
CS9	46.90	4524.61	9.98	32.15
CG Mean ± SD	44.30 ± 3.94	3343.14 ± 652.93	10.41 ± .43	37.70 ± 7.04

* group data presented as mean ± standard deviation

Changes in Performance Indicators : Treatment Group

Initially, box-plots of the treatment group's data were displayed to show a visual trend in the change of each performance indicator over time. As shown in figure 1, the median of the measurements at week 9 is shows a slightly higher trend than the medians of the measurements at the other two time points, and no decreasing trend during the overload at week 5. Figure 2 shows the performance indicator, explosive power, measured in watts, and expressed as the vertical jump scores relative to the athlete's body mass. There is also an increasing trend in the median of the explosive power measurements over time, with no decreasing trend at week 5. Figure 3, illustrates the median of agility measurements over time. At week 5, agility performance indicates a decreasing trend compared to week 1 followed by an increasing trend above baseline at week 9. Furthermore, figure 4, shows a general increasing trend in the median of anaerobic power performance over the eight-week training period, with no decreasing trend at week 5.

Figure 1: Box-plot of vertical jump measurements (in cm) of the treatment group athletes at three time points. The label 1 corresponds to baseline or week 1, 2 corresponds to week 5 and 3 corresponds to week 9.

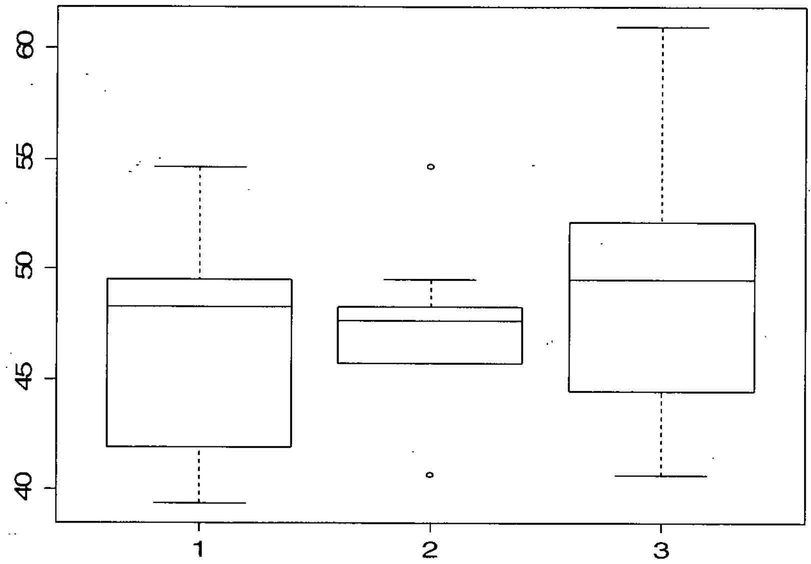


Figure 2: Box-plot of explosive power measurements (in watts) of treatment group

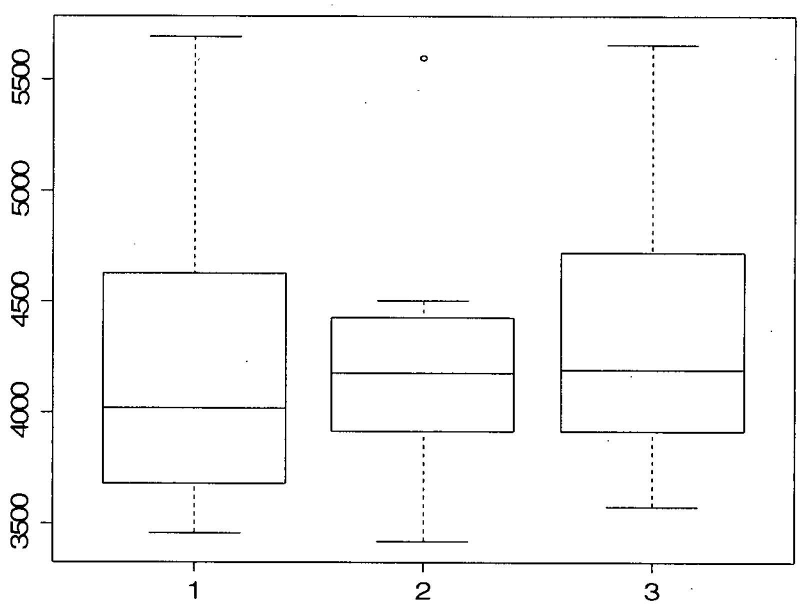


Figure 3: Box-plot of agility measurements (in seconds) of treatment group

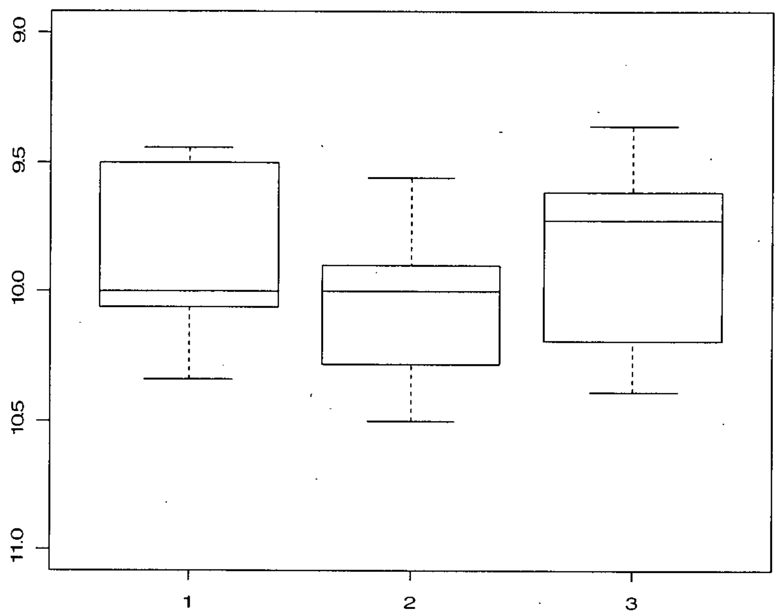
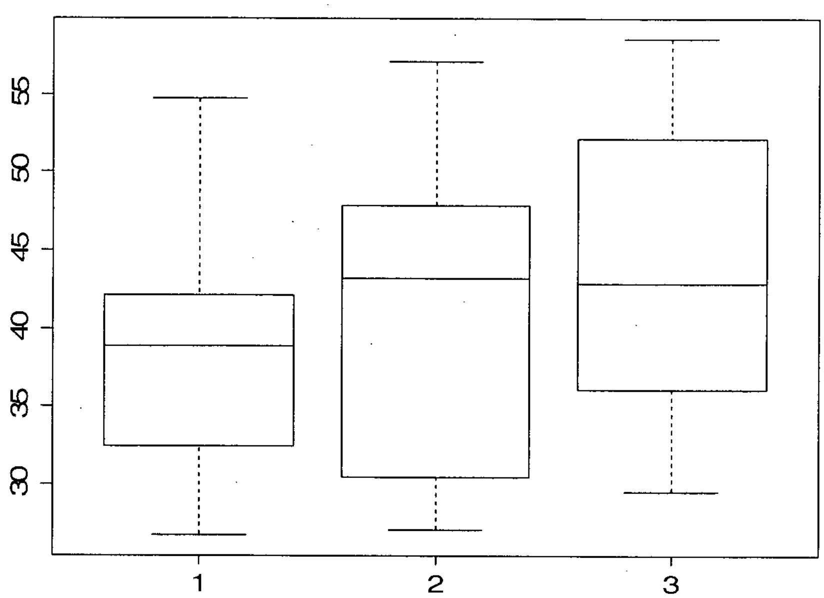


Figure 4: Box-plot of anaerobic power measurements (in seconds) of treatment group



Multivariate Analysis of the Treatment Group

The observations from the descriptive statistics and box-plots give the researcher an idea about the trends over time in the different performance indicators in the treatment group. A more formal statistical test was conducted to confirm whether the changes over time were significant. Multivariate tests were performed on the pair-wise differences of the measurements at any two, time points of each performance variable. For each of the three testing time points a difference was taken for each of the four performance indicators.

Instead of using original values, the pair-wise differences were used assuming that repeated measurements on the same individual are correlated. By taking the differences, the variability due to subjects was eliminated and thus having very precise estimate of error variability, which was needed for the significance tests.

Three multivariate tests were performed, one for each of the pair-wise differences on the four dependent variables (performance indicators). The level of significance was taken to be alpha =.05.

Treatment Group Baseline (week 1) compared to Week 5

Multivariate tests were conducted for the pair-wise differences of week 5 and week 1 (baseline) measurements of the 4 performance indicators in the treatment group. We found the differences between week 5 and week 1, were not statistically significant ($p = 0.373$). Even though the mean scores were higher at week 5, there was no significant change of the four performance indicators from week 1 to week 5 in the treatment group. The observed power was 0.214, which is low to detect a small to moderate difference. This is may be due to very small sample size (n=10), although the estimated effect size is moderate (Partial Eta square = 0.461).

Treatment Group Baseline (week 1) compared to Week 9

Multivariate tests were conducted for the pair-wise differences of week 9 and week 1 (baseline) measurements of the 4 performance indicators in the treatment group. The MANOVA analysis of differences of the measurements at week 1 from those at week 9 found the estimated effect size is big but low power (0.405) fails to detect it. So, on the basis of such a small sample we cannot be confident enough to declare statistically significant changes from week one (baseline) to week nine in the treatment group (p=.141).

Treatment Group at Week 5 compared to Week 9

Multivariate tests were conducted for the pair-wise differences of week 5 and week 9 (baseline) measurements of the 4 performance indicators in the treatment group. The MANOVA analyses of the differences of the measurements between week 5 and week 9 found significance at the 5% level (p = .041).

Follow-up univariate analysis (ANOVA) was conducted to confirm which variable contributed significantly to produce multivariate significance at 5% level. The mean agility score at week 5 was found to be significantly higher at than that at week 9, (p= 0.009) indicating an increase in agility performance at week 9 for the treatment group from week 5.

Treatment Group vs. Control Group

To evaluate the effectiveness of the training program we compared the performance indicators in the treatment group with those in the control group. In this study, measurements were taken over time for both the treatment and control groups. Three repeated measurements (baseline, week 5 and week 9) were taken for the treatment group and two (baseline and week 9) for the control group. Since no measurements were taken at week 5 for the control group, a valid comparison was made comparing the changes in performance indicators from week 1 to week 9 for the two groups.

Since, the athletes in the treatment group had very different baseline measurements from the athletes in the control groups, it was not be meaningful to compare the original performance scores. Instead, we compared the differences of pre-training (week 1) measurements from the post-training (week 9) measurements. By taking the differences, the baseline effect was eliminated from each group, thus making comparison of treatment groups valid. After taking the differences of pre-training measurements from the post-training measurements, for each of the four performance indicators, a multivariate two-sample t-test (Hotelling's T^2 test) was performed to see if there was any group difference for each dependent variable.

The multivariate test results indicate that the treatment group variable is not significant (p= 0.308). Follow-up univariate tests (ANOVA) of group differences for each of the performance indicator also found differences between the control and the treatment subject groups were not statistically significant for any of the four performance indicators: vertical jump (p=.254), peak power (p=.261), agility, (p=.288) and anaerobic power, (p=.340) That is, changes in the performance indicators over time are similar in treatment and control group.

Changes in Performance Indicators : Individual athletes in Treatment Group from Week 1 (baseline) to Week 9

Group means and medians do not allow the researcher to analyse how each individual athlete responded to the eight week training period and how performance of each indicator was affected by the program. Table 5, 6, 7 and 8 represent the individual athlete scores at baseline and after the training period. A calculated percent change in values over time for vertical jump, peak power, agility and anaerobic power was conducted, although findings were not statistically significant. Figures 5 through 8 illustrate these changes in a histogram format. Notice that 8 of 10 subjects improved their vertical jump and subsequent peak power scores. 6 of 10 subjects improved their agility scores and 8 of 10 subjects improved their anaerobic power scores from baseline to week 9. It is difficult to make generalizations about this data until the adaptation logs were quantified. Some athletes may have been in a chronic fatigued state thus preventing them from seeing improvements in the performance indicators tested.

Vertical Jump

The treatment group mean vertical jump scores showed a trend towards increasing, (2.15 cm), although it was not found to be staitistically significant (p=.141). From a coaching standpoint, this is a very noteworthy improvement, even though the control group also improved 3.94 cm. The treatment mean group baseline was 6.91 cm higher, which lends to the rationale that the treatment group are already very close to their biological ceiling.

Peak Power

Although, not statistically significant, (p=.141), peak power also showed a trend toward increasing. The average increase in peak power was 170.92 watts. The control group did show the same trend as well, with a mean increase of 309.09 watts.

Agility

Agility performance for the treatment group showed an increasing trend. Although not statistically significant from week 1 to week 9 (p=.141) the mean increase of 0.62 seconds. The control group showed a mean increase of 0.06 seconds.

Anaerobic Power

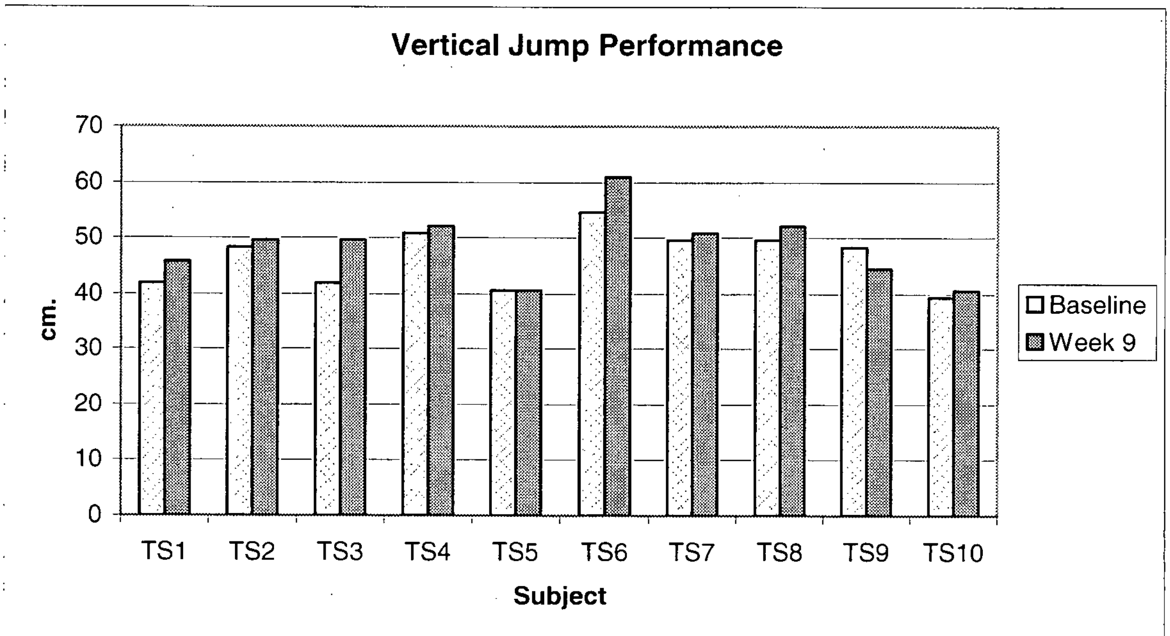
The average anaerobic power scores for the treatment group showed a trend in improvement of 4.35 seconds, although not statistically significant (p=.141) whereas the control group also showed a similar trend with a difference of 2.37 seconds.

Table 5: Pre and Post Vertical Jump Values for Treatment Subjects (p=.141)

	Vertical Jump Baseline (cm)	Vertical Jump Week 9 (cm)	Δ Values (cm)	% Change (post-pre)/pre
TS1	41.91	45.72	3.81	9.1
TS2	48.26	49.50	1.24	2.6
TS3	41.91	49.50	7.59	18.0
TS4	50.80	52.07	1.27	2.5
TS5	40.64	40.64	No change	No change
TS6	54.61	60.96	6.35	11.6
TS7	49.53	50.80	1.27	2.5
TS8	49.53	52.07	2.54	5.1
TS9	48.26	44.45	-3.81	-7.0
TS10	39.37	40.64	1.27	3.2
Mean ± SD	46.48 ± 5.12	48.64 ± 6.11	2.15	4.63%

Δ Values is an indication of the change in the individual vertical jump score from week 1 to week 9; cm, centimetres, % change, percent of change when baseline scores are subtracted from week 9.

Figure 5. Histogram of Individual Vertical Jump Performance Changes



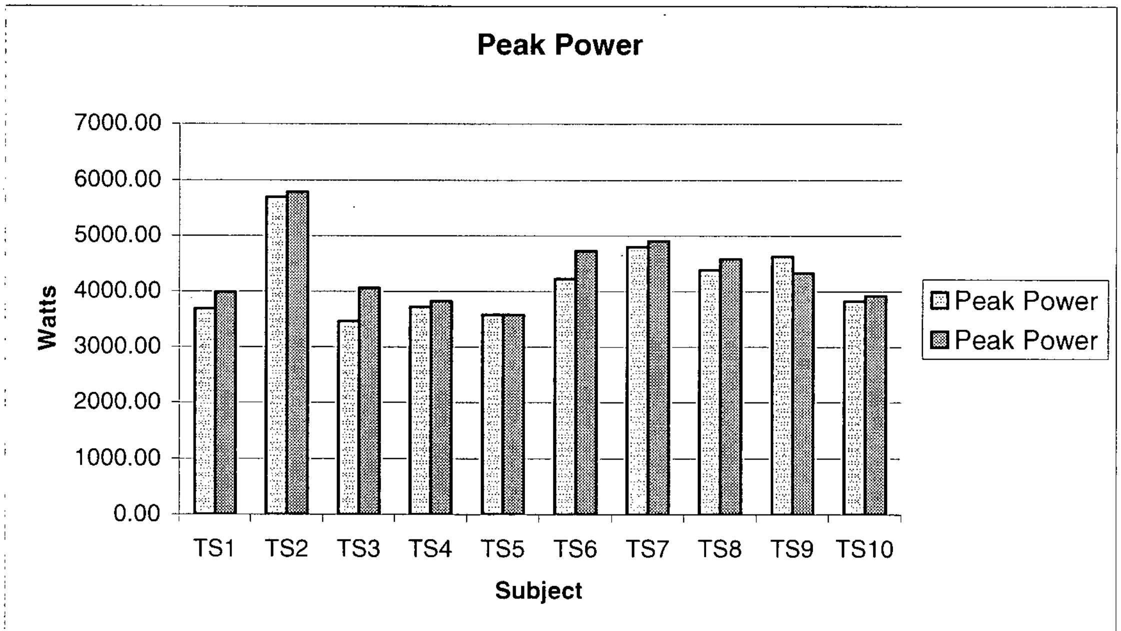
**8 of 10 athletes in the treatment group improved vertical jump scores

Table 6: Pre and Post Peak Power Values for the Treatment Group (p=.141)

	Peak Power Baseline	Peak Power Week 9	Δ Values	% Change (post-pre)/pre
TS1	3680.64	3979.61	298.97	8.12
TS2	5693.17	5788.69	112.3	-0.71
TS3	3459.73	4055.31	595.6	17.21
TS4	3718.28	3817.94	99.66	2.68
TS5	3575.73	3575.73	0.00	0.00
TS6	4221.59	4719.88	498.29	11.80
TS7	4795.87	4897.88	102.01	2.13
TS8	4375.79	4577.46	201.67	4.61
TS9	4626.14	4327.17	-298.97	-6.46
TS10	3818.17	3917.83	99.66	2.61
Mean ± SD	4196.51 ± 697.83	4365.75 ± 654.05	170.92	4.03%

Δ Values is an indication of the change in the individual score from week 1 to week 9; cm, centimetres, % change, percent of change when baseline scores are subtracted from week 9.

Figure 6. Histogram of individual peak power scores



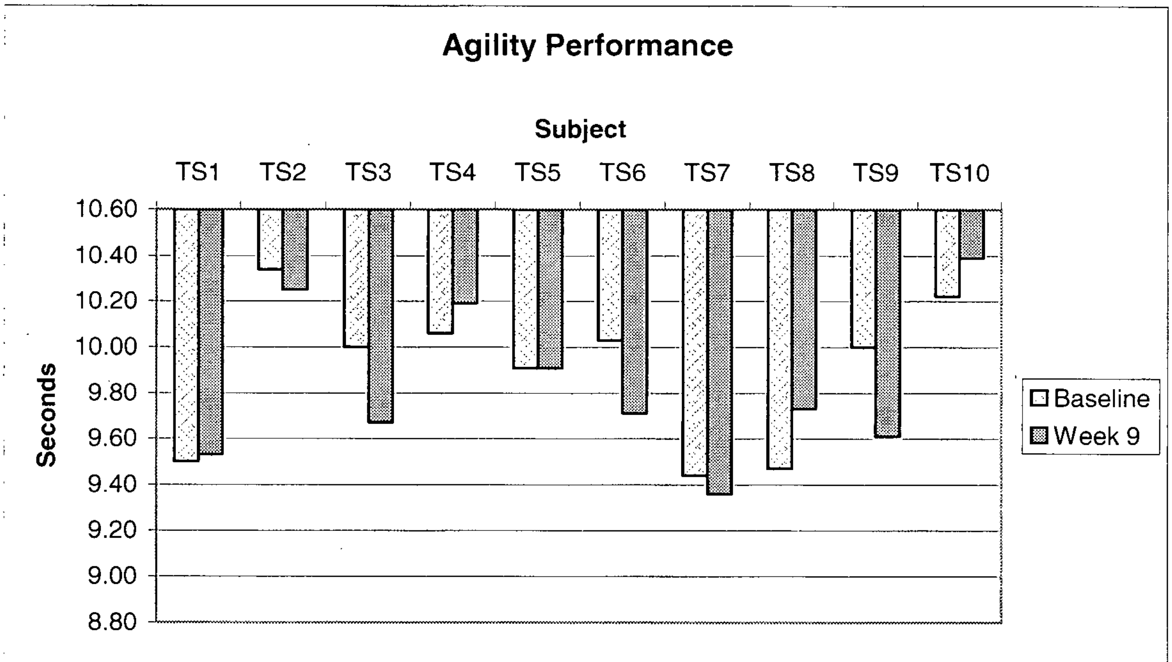
8 of 10 athletes improved peak power scores

Table 7. Pre and Post Agility values for the treatment group (p=.141)

	Agility Baseline	Agility Week 9	Δ Values	% Change (post-pre)/pre
TS1	9.5	9.53	-0.03	0.32
TS2	10.34	10.25	0.09	-0.87
TS3	10.00	9.67	0.33	-3.30
TS4	10.06	10.19	-0.13	1.29
TS5	9.91	9.91	0	0.00
TS6	10.03	9.71	0.32	-3.19
TS7	9.44	9.36	0.08	-0.85
TS8	9.47	9.73	-0.26	2.75
TS9	10.00	9.61	0.39	-3.90
TS10	10.22	10.39	-0.17	1.66
Mean ± SD	9.90 ± .32	9.84 ± .34	.62	-.63%

Δ Values is an indication of the change in the individual score from week 1 to week 9; cm, centimetres, % change, percent of change when baseline scores are subtracted from week 9.

Figure 7. Histogram of individual agility scores



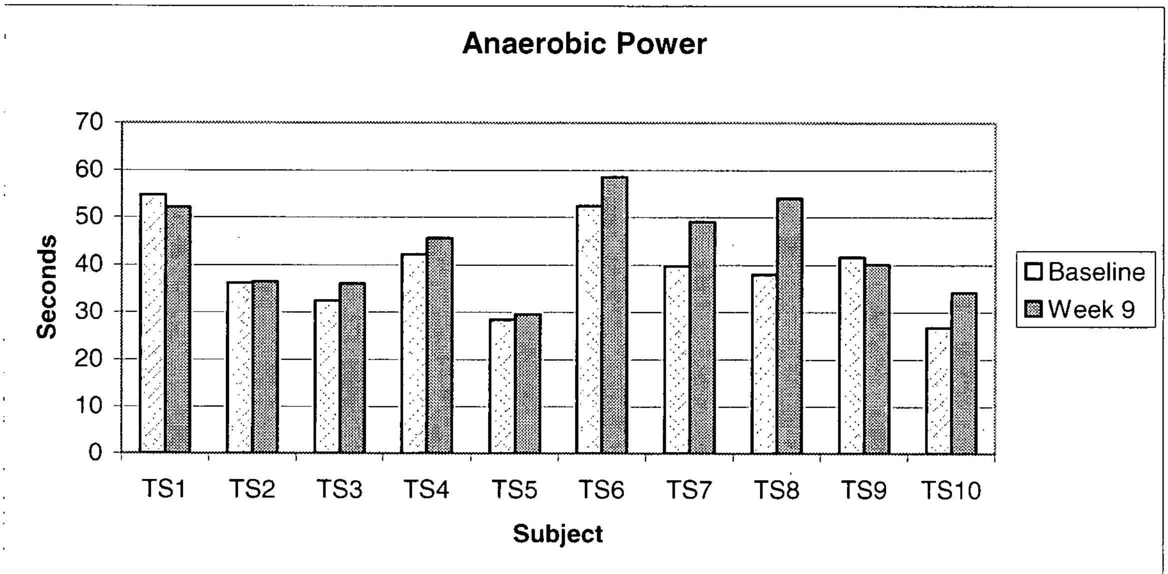
*Scores are inverted to reflected an improvement with a lower score;5 athletes improved

Table 8: Pre and Post Anaerobic Power Scores for the Treatment group (p=.141)

	Anaerobic Power Baseline	Anaerobic Power Week 9	Δ Values	% Change (post-pre)/pre
TS1	54.72	52.16	-2.56	-4.68
TS2	36.22	36.48	0.26	0.72
TS3	32.44	36.10	3.66	11.28
TS4	42.19	45.60	3.41	8.08
TS5	28.34	29.50	1.16	4.09
TS6	52.41	58.59	6.18	11.79
TS7	39.75	49.10	9.35	23.52
TS8	37.97	54.00	16.03	42.22
TS9	41.65	40.16	-1.49	-3.58
TS10	26.72	34.20	7.48	27.99
Mean ± SD	39.24 ± 8.72	43.589 ± 9.20	4.35	11.08%

Δ Values is an indication of the change in the individual score from week 1 to week 9; cm, centimetres, % change, percent of change when baseline scores are subtracted from week 9.

Figure 8. Histogram of individual anaerobic power scores



8 of 10 athletes improved their anaerobic power scores

Changes in Performance Indicators : Individual athletes in the control group from Week 1 (baseline) to Week 9

Table 9: Pre and Post Vertical Jump Scores for the control group

	Vertical Jump Baseline	Vertical Jump Week 9	Δ Value	% Change (post-pre)/pre
CS1	48.26	48.26	0	0.00
CS2	34.29	41.91	7.62	22.22
CS3	48.26	45.72	-2.54	-5.26
CS4	41.91	44.45	2.54	6.06
CS5	38.10	41.91	3.81	10.00
CS6	35.56	41.91	6.35	17.86
CS7	44.45	50.80	6.35	14.29
CS8	31.75	36.83	5.08	16.00
CS9	40.64	46.90	6.26	15.40
Mean ± SD	40.36 ± 5.61	44.30 ± 3.94	3.94	9.77%

Δ Values is an indication of the change in the individual score from week 1 to week 9; cm, centimetres, % change, percent of change when baseline scores are subtracted from week 9.

Table 10: Pre and Post Peak Power Scores for the Control Group

	Peak Power Baseline	Peak Power Week 9	Δ Values	% Change (post-pre)/pre
CS1	2906.77	2906.77	0.00	0.00
CS2	2115.18	2713.17	597.99	28.27
CS3	3225.11	3025.80	-199.31	-6.18
CS4	3501.82	3701.13	199.31	5.69
CS5	2478.59	2777.56	298.97	12.06
CS6	2290.85	2789.13	498.28	21.75
CS7	3843.28	4341.56	498.28	12.96
CS8	2909.94	3308.56	398.62	13.70
CS9	4034.92	4524.61	489.69	12.14
Mean ± SD	3034.05 ± 636.72	3343.14 ± 652.93	309.09	10.19%

Δ Values is an indication of the change in the individual score from week 1 to week 9; cm, centimetres, % change, percent of change when baseline scores are subtracted from week 9.

Table 11: Pre and Post Agility Scores for the Control Group

	Agility Baseline	Agility Week 9	Δ Values	% Change (post-pre)/pre
CS1	9.78	9.74	.04	-0.41
CS2	10.60	10.07	.53	-5.00
CS3	10.16	10.13	.03	-0.30
CS4	10.62	10.79	-.17	1.60
CS5	10.78	11.03	-.25	2.32
CS6	10.79	10.96	-.17	1.58
CS7	10.47	10.52	-.05	0.48
CS8	10.88	10.50	.38	-3.49
CS9	10.19	9.98	.21	-2.06
Mean ± SD	10.47 ± .34	10.41 ± .43	-.06	-.57%

Δ Values is an indication of the change in the individual score from week 1 to week 9; cm, centimetres, % change, percent of change when baseline scores are subtracted from week 9.

Table 12: Pre and Post Anaerobic Power Scores for the Control Group

	Anaerobic Power Baseline	Anaerobic Power Week 9	Δ Values	% Change (post-pre)/pre
CS1	45.00	50.00	5.00	11.11
CS2	39.75	43.21	3.46	8.70
CS3	44.09	45.35	1.26	2.86
CS4	32.06	35.87	3.81	11.88
CS5	37.63	36.51	-1.12	-2.98
CS6	22.78	26.60	3.82	16.77
CS7	35.00	38.66	3.66	10.46
CS8	27.88	30.90	3.02	10.83
CS9	33.75	32.15	-1.6	-4.74
Mean ± SD	35.33 ± 6.84	37.69 ± 7.04	2.37	6.68%

Δ Values is an indication of the change in the individual score from week 1 to week 9; cm, centimetres, % change, percent of change when baseline scores are subtracted from week 9.

Adaptation trend in the treatment group

In order to examine the trend of adaptation for each athlete in the treatment group, time series plots of the logarithm of adaptation indicators (stress, fatigue, sleep quality and DOMS) have been displayed in the discussion section as figures 9 to 18. These adaptation indicators are plotted against time (weeks one through eight of pre-season training). Some of the adaptation indicators have very high numeric values (e.g., tact) compared to others. It is most important to note the shape of each line over time as the athletes are exposed to more intense training and practice sessions. No formal analysis was conducted on the logarithms.

Discussion

The ultimate goal of designing training programs for athletes is to optimize performance. Basketball is a comprehensive sport requiring a combination of individual skill, team play, power, speed, experience, anaerobic capacity and the ability of these factors to culminate during competition. This research attempted to measure changes in vertical jump, peak power, agility and anaerobic power in two similar women's basketball teams.

In the current study, initial baseline performance differences were taken into account during the statistical analysis. Multivariate analyses were conducted on changes over time with respect to the treatment group alone, and also in comparison of both groups. Statistically, no significance was found in all four dependent variables over time in the treatment group, with the exception of agility, which improved from week 5 to week 9. When the treatment group was compared to the control group, in pre and post measures, no significance was found all four dependent variables, thus possibly implying that the pre-season strength and conditioning program had no effect on the four performance indicators measured.

Group Physical Characteristics

The mean height of the treatment subjects profiled in this study (178.83 cm) was slightly higher when compared to values previously reported for NCAA Division 1 women's basketball (177.45 cm, n=46) (Lamonte et al, 1999). The mean weight of the treatment subjects profiled in this study was 75.29 kg, 4.92 kg heavier than the NCAA division 1 data. Interestingly, changes in body weight were not seen across the eight-week pre-season for both subject groups involved in the present study, perhaps due to the short experimental period. This is consistent with results posted by Hakkinen who looked at physiological changes in female NCAA division 2 players over 4 years of basketball and found no significant changes in weight (1993).

Baseline $V0_2$ max scores for both groups were also consistent with findings by Petko and Hunter (1997), where they documented scores of 39.5 ml/kg/min ± 5.7 for female basketball athletes. The testing protocol used by Petko et al did differ, as they used a 1.5 mile run to obtain a VO_2 max score.

It should be mentioned, the athletes in the treatment group were well-conditioned as compared to their NCAA Division 1 and 2 peers, therefore any improvements in sport-specific performance indicators is notable, even though the control group did see even greater improvements in vertical jump performance.

Performance Changes

Muscular power, as it relates to elite basketball performance, has been measured by a number of techniques. In the present study increases in maximal power output and leg speed or agility were assessed by measuring changes from baseline to week 9 in vertical jump and agility. Mean performance for both groups improved on all performance indicators over the 8-week period.

Lamonte's research on vertical jump, for the NCAA division 1 group was 48.21 ± 8.53 cm, which is slightly lower than the post-test mean results of the treatment group in this study (48.64 ± 6.11 cm). An identical countermovement protocol was also administered to Lamonte's NCAA group, indicating that the results for each group can be validly compared. Vertical jump scores at week 9, for the treatment group, although statistically insignificant when compared to the control group do indicate a very high level of performance when compared to NCAA division 1 scores, a noted superior league.

A study, investigating normative values for common pre-season testing protocols in NCAA division 2 female basketball athletes by Schweigert in 1996, found the average vertical jump, to be 45.97 cm, using the same countermovement protocol, which is far below the treatment group average in this study. Mean scores from the treatment group at week 9 fall into the 60^{th} percentile when compared to NCAA Division 2 athletes (Schweigert, 1996). To make the 90^{th} percentile, a vertical jump of 57.15 cm must be achieved. One athlete in the treatment group jumped 60.96 cm at week 9.

There are several factors, which can influence the success of a program to develop lower body muscular power. The overall volume of jumping performed by the athlete in training will influence vertical jump performance (Young, 1995), therefore adherence to plyometrics and sport practice and staying injury free is key. These athletes often show an increase in vertical jump performance at a faster rate than athletes who are involved in non jump related sports, or are not as exposed period.

Factors affecting vertical jump performance in the literature include the percentage of fast twitch muscle fibers, motor unit activation and synchronization and specificity of the movement pattern (Sale, 1998). Exposure to plyometic training is also identified as a factor, which can affect an athlete's ability to make efficient use of the elastic properties of his/her muscles in a stretch-shortening type of contraction (Shorten, 1987). It has also been suggested that some athletes have a slower stretch-shortening cycle than others, or may be proficient at one, but not the other (Schidtbleicher, 1990). Furthermore, power performance is affected by the interaction between agonist, antagonist and synergists involved in the joint movements (Young, 1993). Therefore, specific training movements will reduce the co-contraction of antagonists and increase the coordination of agonist and synergistic activity (Schmidtbleicher, 1992; Young, 1993).

It has also been investigated that there is no significant correlation between percent body fat and jump performance ($r= -0.21$, $p<0.05$) (Ashley & Weiss, 1994) thus establishing the rationale behind why weight was the only anthropometric measure taken in this study. Changes in vertical jump and peak power monitored by Petko and Hunter, over a four year period were found to be the greatest of all performance indicators tested with a mean percent change of 5.3% from freshman year to senior year (pp. 47). Perhaps the significant changes over 8-weeks in both groups can be explain to exposure to the sport itself, which is plyometric in nature. And the larger increases made by the control group in this study could be due to the fact that they have more room to improve and reach their biological ceiling. If superiority in strength/power is shown in short term studies, such as the present one, it may merely imply that the program, or basketball practice alone, brings about neural factor gains (Fleck, 1999). Furthermore, it has been shown that strength/power gains occur at a slower rate and a smaller rate in highly trained (treatment group) versus moderately trained (control group) subjects (Fleck, 1999). Thus the magnitude of change and the rate of change is often dependent on the baseline measures of the group being tested.

Another hypothesis for the differences seen in group changes with respect to vertical jump performance could be the impact of concurrent training effects. This applies to the athletes in the treatment group where practices were more frequent and longer and may have had a higher aerobic component (more running drills), which can comprise maximal gains made in explosive power (Dudley & Fleck, 1987). In short, aerobic training can interfere with power training.

Combining weight training and plyometrics, "complex training" did deem to be effective in improving overall vertical jump performance of the treatment group in this study. Because this training technique was not isolated, we do not know what degree its design contributed to the results, or if plyometric training, or weight training alone could have produced the same effects. It appears that a complete program to improve vertical jump must include resistance training, complex training and plyometrics as shown by the results of this study (Klinzing, 1991). It would be logical to assume that by combining Olympic lifting, weight training, plyometrics and agility training over the course of a pre-season phase, power would be improved. Due to the multi-faceted nature of vertical jump performance, a single training method approach may not be as effective as combining proven training methods to provide variation in stimulus and to increase the overall training adaptation (Ebben, 2002; Newton and Kraemer, 1994).

Agility

The vertical jump test is known to have low validity as a predictor of performance on the T-test (Pauole et al., 2000), as the relationship between leg power and agility is moderate to low ($r = .11$) (Pauole et al., 2000). The t-test, was found to be useful for assessing lower extremity movement skills and coordination in this study. Overall, agility scores for the treatment group (mean = 9.84 seconds) fall above the 90th percentile for college-aged females (Pauole et al.,2000). No published norms are available for female basketball athletes. Agility scores for the treatment group declined at week 5, with 7 of 10 athletes producing results slower than those at baseline. The gains made from week 5 to week 9 for the treatment group were statistically significant, indicating that perhaps the athletes are most agile when they are well-rested and not weight training as frequently or intensely. Leg speed and agility did increase for both groups in this study, but the increases were small. Three of 10 subjects in the treatment group saw greater than 3 tenths of a second improvement in T-test time, which is notable from a coaching standpoint. Two of 9 subjects in the control group improved greater than 3 tenths of a second. The baseline differences between the control group and the treatment group were statistically significant, which may lead the investigator to imply that the improvements made in the control group were simply due to transfer of learning effects, whilst the treatment group engaged in the movement patterns involved in the t-test as part of their conditioning program, thus contributing to the team improvement. Furthermore, conclusions made by Young and Sheppard in regards to optimizing agility training programs is that there is no consensus on frequency and volume (Interview, 2005). Sheppard states that it is preferred to perform "15-20 minutes of agility, more frequently during a microcycle versus, longer sessions of 50 minutes or more, less frequently." Young also states "Usually one session a week isn't enough for development of any quality but basketball drills are probably training agility without intending to" (Interview, 2005). Perhaps agility training is optimal in the off-season with more frequency and during the pre-season, basketball practice can offer movement skill and leg speed benefits.

Anaerobic Power

The present findings indicate that basketball-specific anaerobic power training with university-aged females enhances intermittent, high-intensity fitness. Incorporating multi-directional anaerobic interval training into a pre-season training program, while eliminating the focus on aerobic training improved bioenergetics related to game performance. The two subject groups were matched on this variable at baseline testing making interpretation of the results an easier task. The treatment group, although, statistically insignificant, showed a trend towards improvement by 4.35 seconds on the anaerobic speed test, whereas the control group improved only by 2.37 seconds. This concludes that the anaerobic conditioning sessions, over and above sport practice, may have helped the treatment group athletes improve their basketball-specific fitness. Since the control group did improve as well, perhaps at the college level, where resources and time are limited, basketball-specific fitness can be targeted during practice and game times.

Limitations from previous performance-based research:

Designing research-based team training for basketball is a complex undertaking. There is limited research on basketball-specific training protocols; instead there is information on periodization and program design as well as sport analysis, which leads to the strength and conditioning specialist inferring about what is best for his or her team of athletes. Also, studies that have been done have neglected to provide detail on the independent variable, not allowing the researcher to easily replicate the experimental design; there is lack of documented detail on volume, intensity, tempo and technique required for performance (Wilkes, 1995). In regards to testing procedures, there is no standardization of experimental procedures and testing protocols for the sport of basketball to compare normative data amongst the population. Also, the subjects are often unequally distributed in relation to training background and baseline strength and conditioning levels making it difficult to infer a prescription that is optimal for an entire team (Wilkes, 1995). Furthermore, in the past, training studies did not often use a control group to compare the effects of the independent variable. Therefore the dependent variable could have been influenced by anything. Overall, the major limitation with regards to the current research is that there appears to be a shortage of studies comparing normative data on performance in attempt to explain differences in athletic ability and sport-specific performance indicators.

Practical Applications

The implementation of an eight-week, periodized, pre-season training program prior to the basketball season is necessary for performance at an elite level, where speed and power are definitive performance factors for success. The profile of this select group of female university basketball players should give investigators insight into the expected outcomes during testing sessions with similar level athletes in the future investigations. It is apparent that the treatment group athletes in this study are a more physically elite group when compared to the controls, likely as a result of a more extensive training history and more rigorous training protocols. Based on sport analysis, norms available and the findings of the present study, coaches should utilize tests of anaerobic power in developing recruiting criteria and rely less on aerobic measures of basketball-specific fitness. The correlation between aerobic power and anaerobic power is virtually non-existent (r= -0.23) (Hoffman, 1999). Gillam (1985), found the relationship between points scored per minute of play and cardiovascular endurance were not correlated. These findings support the rationale that perhaps success in basketball may depend on the player's anaerobic endurance than aerobic endurance (Gillam, 1985). Furthermore, training protocols that combine a undulating model of periodization, plyometrics and weight training as a varied stimulus for explosive power, and agility drills, (or sport practice drills) that involve change of direction versus linear speed will result in improvements in the performance indicators necessary for basketball.

Adaptation to the Training Stimulus

The ability to accurately control and monitor internal training load is an important aspect of effective coaching. The RPE method, used in this study, as a subjective evaluation of training intensity, during intermittent training, and team sport practice and competition, may provide a good method for quantifying training intensity. The present data suggests it is user friendly, reliable and consistent with the investigator's intended level of intensity for each session. To be able to calculate a daily exercise score, or a training load, quickly, is of great practical use to the strength and conditioning coach.

"The primary indicator of either overreaching or overtraining is a decrement in performance" (Hoffman, 2000, pp. 56). The use of performance measures: strength, speed and agility appears justified in the research, and is suggested, in this study, to be an effective and inexpensive method for monitoring athletes for overtraining, or perhaps, more accurately, overreaching. Interestingly, the most sensitive test for highlighting players who were fatigued was the T-Test of agility, as 7 of 10 of the treatment group athletes saw declines in performance at week 5 after a loading phase. Hoffman's research also revealed that the 27 meter sprint test was the most sensitive test for players who were fatigued (2000). 5 of 10 treatment group subjects also saw declines in vertical jump performance at week 5, even though 80% of the team improved by week 9. Further analysis of the training log revealed an increase in training volume at week 4 and global increases in fatigue rated by most of the athletes in the treatment group at weeks 4 and 5.

This noted fatigue can cause a loss of sustained muscle activity and maximal force production. Often it is exercise-induced or related to metabolic variables such as concentration of phosphates or hydrogen ions in the muscle, which is likely the result of increasing overall program intensity at week 4. A reduction in the frequency of motor unit potentials, or a reduced number of cross-bridge interactions, or structural damage to the sarcomere arrangement can cause reductions in muscle force output and reductions in performance on both explosive power tests and agility tests (Armstrong, 1984).

As Marsit (1994), noted in his strength and conditioning article for women's basketball, the goals for a basketball program include: "Decreasing injury potential" (pp. 70). It is also worth noting that 0 of 10 treatment group athletes suffered any overuse or catastrophic injuries during the treatment period. The musculoskeletal system appeared to adapt to the increased load and was prepared to handle the demands of training 10-12 times per week continuously for 8 weeks. Plyometric training is an established technique for enhancing athletic performance but the program may have also "facilitated beneficial adaptations in the sensorimotor system and enhance dynamic restraint mechanisms" (Chimera at al, pp 24, 2004), which prevented major injuries. Although not a direct objective of this study, this "side-effect" of the training program allowed the head coach to work with 10 healthy athletes as she prepared them for the upcoming competitive season. This is likely more valuable than improvements in performance as the health of the team will often dictate a team's success.

Individual Results

It is certain, that overtraining syndrome is the result of a disparity between training load and tolerance of the load and according to this explanation, OTS should not be discussed solely in clinical terms, but more so under the umbrella of training content (Hartmann & Mester, 2000). Individual exercise tolerance combined with coping ability to outside stressors is a key factor in athlete monitoring.

In the present study, training and practice load were calculated and quantified from the athlete's daily journal as a weekly stress score. DOMS, fatigue, sleep quality and stress were also quantified and given a weekly adaptation score. All of these scores were plotted on the logarithm against time and each weekly value, for each variable is tabulated below the logarithm for each athlete. The adaptation indicators for predicting overtraining syndrome or performance declines (Ratings of stress, sleep quality, fatigue and muscle soreness) provides the coach with the possibility of establishing which individual athletes are adapting, or not, to the program. This research suggest that daily logs of training and measures of adaptation, completed by the athlete, may assist in programming appropriate training loads during intense training and tapering. Although the reliability of the athlete logbook may be questioned, it appears that even a brief recording of how the athlete feels may provide useful information for the coach if it is completed on a daily basis.

In this study, the taper in training load did appear to provide most of the subjects with enough recovery prior to the start of the competitive season. DOMS, did not appear to affect group performance and could be due to the fact the treatment group had completed an off-season plan and summer time scrimmages and were somewhat accustomed to eccentric exercise. This descriptive examination in the use of performance testing after an overloading phase to monitor how well a basketball team is adapting to the training program and practice/game schedule appears to provide an acceptable warning system for coaches.

Treatment Subject 1 (TS1)

This athlete completed 5 of 7 Monday lifting sessions, 6 of 6 Tuesday plyometric and agility sessions, only 4 of 8 Thursday complex training sessions and all 5 Friday conditioning sessions. She improved her overall vertical jump score by 3.81 cm, which translated to a peak power improvement of 298.97 watts. Her vertical jump score did show an interesting trend where it initially increased dramatically by 6.35 cm, and then it decreased by 2.54 cm. She seemed unaffected by the increased training load at week 4. Her anaerobic power, initially the highest on the team, declined by 2.56 seconds at week 9. These gains in vertical jump and power performance are not congruent with her lack of commitment to resistance training and complex training during the pre-season. This athlete documented a commitment to skills practice instead and chose to miss work-out to shoot, as evidenced by her log. She did attend all 6 plyometric and agility sessions and perhaps that training alone improved her performance in vertical jump. Although agility performance showed no real change, the decline on the anaerobic power score does not reflect the commitment to this training parameter. It is important to note that during week 2, TS1 suffered a sprained ankle, which she continued to train on. During the rest of the pre-season period, she did not document any further mention of the injury or any rehabilitative protocols undertaken.

Figure 9 represents TS1. This athlete documented an even load of sport practice over the eight-week treatment period with no major perceptions of increase or decrease. She did note a large decrease in training load at week 3 with a subsequent rise at week 4, which is when the investigator increased the load. From there it appears to level off for weeks 5 and 6 and then decreases by week 7, indicating a perceived acknowledgement of the taper. DOMS peaked at weeks 2 and 3 corresponding to the increased perceived training load, with a decreasing trend over the rest of the pre-season phase. Sleep quality, became worse by week 4 and was fairly consistent prior to week 4 and after week 4. Stress levels actually increased over the treatment period and peaked at week 7. Fatigue levels increased and peaked at week 4, where sleep quality was rated the poorest and decreased by week 6 and then increased again slightly at the end of the preseason period. These rises in scores for adaptation indicators may account for the decrease in performance on testing results of agiity and anaerobic power at week 9.

Treatment Subject 2 (TS2)

This athlete completed 5 of 7 Monday lifting sessions, all 6 plyometric and agility sessions, only 5 of 8 Thursday complex training sessions and 4 of 5 Friday anaerobic conditioning sessions. She documented knee pain for the first 4 weeks of the pre-season period. Her results for vertical jump improved by 1.24 cm by week 9 despite the small decrease in jump performance at week 5 of 1.26 cm. This decrease at week 5 could be due to the knee pain she was suffering daily for the first 4 weeks. Her agility score showed a steady improvement at both testing points, improving by .06 seconds at week 5 and a total improvement of 0.09 seconds at week 9. Anaerobic power scores showed an improvement from baseline to week 5 of 3.62 seconds, but then the score declined by 3.36 seconds showing only an overall improvement of only 0.26 seconds by week 9. This small improvement in anaerobic power did not meet the expectations of the conditioning coach.

Figure 10 represents athlete TS2. This athlete documented a fluctuating sport practice load over the 8-week period. Training load had minor fluctuations over time and showed a general declining trend as the competition period neared, which was congruent with the training prescription. DOMS showed a steady profile with no major increases or decreases with altered training loads and more intense sport practices. Sleep quality did, however, show a worsening trend over time, which may explain the very small increases in the performance indicators. Stress and fatigue levels for this particular athlete were rated much higher on the daily 1-10 scales as well. This athlete's anaerobic power performance was very poor and perhaps this was due to maladaptation to factors that caused the poor sleep, subsequent fatigue and high stress levels.

Treatment Subject 3 (TS3)

This athlete completed 6 of 7 Monday lifting sessions, 5 of 6 Tuesday plyometric and agility sessions, 7 of 8 complex training sessions and 4 of 5 anaerobic conditioning sessions. She missed the first week of training camp due to the influenza virus. Her performance in vertical jump and peak power showed an outstanding increasing trend over time, with huge improvements of 6.35 cm at week 5 and a total improvement of 7.59 cm by week 9. Agility scores also showed a steady improvement of 0.1 seconds at week 5 and a final improvement of 0.33 seconds. Anaerobic power decreased at week 5, by 4.35 seconds, but ended up surpassing baseline with an improvement of 3.66 seconds overall by week 9. This athlete demonstrated gains in all performance indicators.

Figure represents TS3. This athlete rated sport practice sessions as increasing in load over time and training load showed a decreasing trend over time, which was congruent with the investigator's prescription. DOMS increased steadily, peaking at week 3 and but had little variation for the most part during the course of the pre-season period. Sleep quality was poorest at weeks 4 and week 7. Stress levels showed increases at week 4 and week 6, but decreased during the last two week of pre-season training. Fatigue was at its greatest at week 4 for this athlete as well, but was generally consistent during the entire treatment phase. The increases in fatigue and stress, at week 4 through

6, may, in part, explain the decline in anaerobic power performance at week 5, but it does not relate to the huge improvement in vertical jump by week 5. This athlete appears to have adjusted to the program as evidenced by the improved performance.

Treatment Subject 4 (TS4)

This athlete had extremely poor adherence to her resistance and complex training program. She completed 0 of 7 of the Monday lifting sessions, 6 of 6 Tuesday agility and plyometric sessions, 0 of 8 Thursday complex training and 5 of 5 Friday anaerobic conditioning sessions. Her vertical jump performance showed a large decline at week 5 by 3.8 cm. Nonetheless, she did regain her power as her week 9 score surpassed her baseline by 1.27 cm, which was still below the team average. Perhaps the plyometric training sessions were sufficient to convert off-season gains in strength to improvements in explosive power. However, agility performance did not improve in this subject. It was highest at baseline and showed a decline at week 5 of .23 seconds and a total decline of .13 seconds at week 9. Anaerobic power peaked at week 5 with an improvement of 5.66 seconds, but overall, it improved by 3.41 seconds (week 9), which is a significant result, perhaps due to her commitment to Friday's conditioning sessions.

Figure 11 represents athlete TS4. This athlete perceived sport practice load to increase over time, while training load showed a dramatic decrease over time, perhaps due to lack of commitment. DOMS peaked by week 4, and showed a decrease in values by week 8, indicating a positive adaptation to the practice and training loads. Sleep quality did not show any trend or pattern as it fluctuated up and down over the treatment period. It was, however, rated high (poor) in comparison to the other treatment group subjects. Stress levels were highest at week 3 and generally consistent for all of the other training weeks. Fatigue appeared to increase abruptly at week 2 and then showed a steady decrease until week 7, where it increased to similar levels as week 2 until the end of the eight-week period.

Treatment Subject 5 (TS5)

This athlete completed of 6 of 7 Monday lifting sessions, 6 of 6 Tuesday agility and plyometric sessions, 8 of 8 Thursday complex training and 5 of 5 Friday anaerobic conditioning sessions. Her vertical jump scores did not change at any testing point during the course of the study, despite her commitment to her plyometric and complex training program. Her rating of perceived exertion on each work-out were higher than 7 out of 10 on most days indicating that this athlete did push herself physically. Agility slowed by .03 seconds at week 5 and was the same as baseline by week 9, indicating no change in this parameter as well. Anaerobic power showed a small decrease of 1.24 seconds at week 5 and at week 9 it improved 1.16 seconds from baseline. This athlete did not show the progress we hoped during the pre-season period.

Figure 13 represents TS5. Her documentation of sport practice fluctuated for all 8 weeks of pre-season training, showing a sharp decrease at week 8. Ratings of perceived exertion for sport practice were quite high with values of 8 and 9 of 10 listed on many days. Training load was indicated by a cleaner decreasing trend in values over time, which was congruent with the investigator's prescription. DOMS peaked at week 3; it was rated much higher than all of the other weeks. Sleep quality was generally consistent throughout the treatment period and reached it highest point at week 7. Stress levels peaked at week 5 after showing a steady increase over the first 4 weeks. Some days, stress was rated a 10, which is the highest possible level. The investigator did communicate with this athlete during midterms, which were during week 4 and 5 and discovered that she was feeling very overwhelmed by the pressures of her exams. Stress was also rated high at week 8, perhaps due to the impending competitive season. Fatigue was also highest at week 5, when stress and sleep quality were both high. Week 5 testing results also revealed either no improvement or declines in improvement, which may lend correlation to these higher adaptation indicator ratings at this time. This athlete's high ratings of maladaptation may be a large part of why this athlete's physical performance indicators did not improve over the treatment period.

Treatment Subject 6 (TS6)

This athlete completed of 7 of 7 Monday lifting session, 6 of 6 Tuesday agility and plyometric sessions (one session was very modified for this athlete), 7 of 8 Thursday complex training sessions and 4 of 5 Friday anaerobic conditioning sessions. TS6 suffered an ankle inversion sprain at week 3, which prevented her for practicing and loading the joint, missing the anaerobic conditioning session that week. She was able to ride a stationary bike for some metabolic training effects. Her test results in vertical jump performance showed no change at week 5, but an impressive improvement of 6.35 cm by week 9. Her agility scores also showed a trend of improvement over time with week 5 improving by .03 seconds and week improving further by .32 seconds. Anaerobic power also steadily improved, first by .43 seconds at week 5, and a total improvement of 6.18 seconds. This athlete showed ideal results in all performance indicators and appeared to peak at the correct time for her season.

This athlete rated sport practice almost the same week to week, except for week 2, where it was rated quite low. Training load showed a steady decrease over time, congruent with the prescription. DOMS peaked at week 3 and week 7. Interestingly, DOMS was rated at 8 of 10 in severity the day TS6 sprained her ankle. This subject took 2 ibuprophen while she was treating her injury, only on the day she injured herself.

Sleep quality was rated consistently high during the eight weeks, indicating that this athlete was perhaps not getting good quality rest. Stress and fatigue were also rated high, but testing results do not reflect a physical maladaptation despite these high values.

Treatment Subject 7 (TS7)

This athlete completed 6 of 7 Monday lifting sessions, 5 of 6 Tuesday plyometric and agility sessions, 6 of 8 Thursday complex training sessions and all 5 Friday anaerobic conditioning sessions. The session she missed were modified due to lower back soreness as documented in her training log book. This athlete improved in all performance indicators. Her vertical jump scores showed a very small drop of .03 cm at week 5, perhaps due to back pain at weeks 3 and 4. It did increase of 1.27 cm from baseline at week 9, below the team average. Her agility performance worsened at week 5, by .12 seconds, but improved overall by .08 seconds, when she indicated that her back was pain free. Her anaerobic power score improved dramatically, rising 5.03 seconds by week 5 and improving by 9.35 seconds at week 9, which was the second most improved on the team.

Figure 15 represents TS7. This athlete rated sport practice the highest at week 2 and week 6, but there was little variation from week to week. Practices were missed on week 3 as this athlete was injured. Training load steadily decreased over time and week 3 it decreased due to modifications made to this athlete's program to accommodate her injury. DOMS showed a distinct peak at week 3, again, perhaps associated with the back pain, with a large drop until week 6. At week 7, DOMS increased again, when this athlete returned higher load resistance training. Sleep quality fluctuated up and down over the eight-week period. Stress peaked at week 3 and week 6, but did show a decrease as competition neared and testing was re-administered. Fatigue also peaked at week 3 and week 6 and showed the same decrease by week 8. The decrease in perceived training load and the timing of this decrease seemed to favour this athlete as indicated by testing results and decreasing ratings of adaptation indicators by week 8.

Treatment Subject 8 (TS8)

This athlete completed 7 of 7 Monday lifting sessions, 6 of 6 Tuesday plyometric and agility sessions, 6 of 8 Thursday complex training sessions and all 5 Friday anaerobic conditioning sessions. Her vertical jump scores declined slightly at week 5, by 1.27 cm, but by week 9 she had a total improvement of 2.54 cm, which was above the team average. Her agility scores worsened over the treatment period, with a decline of .22 seconds at week 5 and an overall decline of .26 seconds, even after completing all 6 plyometric and agility work-outs and not reporting any injuries. Anaerobic power scores improved the most on the team with a 6.53 second improvement at week 5 and a huge, 16.03-second improvement by week 9. Interestingly, this athlete rated anaerobic training sessions as very intense, with values of 9 and 10 on all sessions. She obviously worked quite hard on this parameter.

Figure 16 represents TS8. This athlete rated sport practice fairly consistently over the 8-week treatment period with one major increase in load at week 2. Training load showed a decreasing trend over time, congruent with the prescription and DOMS was rated as zero for the entire pre-season period, with the exception of week 1. Sleep quality fluctuated up and down over the 8 weeks and stress levels did as well, peaking at week 5. Fatigue scores steadily decreased after week 4, where it was at its highest as did rating of stress. These declines in adaptation indicators may explain that this athlete did adapt to the training stimulus and did allow a sufficient taper.

Treatment Subject 9 (TS9)

This athlete completed 4 of 7 Monday resistance-training sessions, 6 of 6 Tuesday plyometric and agility training sessions, 4 of 8 Thursday complex training sessions and all 5 Friday anaerobic conditioning sessions. Her vertical jump scores declined during the eight-week camp. At week 5, she worsened by 2.54 cm and by week 9, she was 3.81 cm below baseline. This athlete was the only athlete who declined on vertical jump performance at week 9. Perhaps her lack of commitment to her complex training sessions did not produce the results we wanted. Agility performance showed more promise with a small decline of .10 seconds at week 5, but an overall .39-second improvement. Anaerobic power showed a decline of .35 seconds at week 5, which from a coaching perspective, is insignificant and an overall decline in performance of 1.49 seconds, which does lead the investigator to believe this athlete's anaerobic power did not improve, even though she was slightly above the team average at baseline testing. This athlete had the worst percent change results for anaerobic power on the team.

Figure 17 represents athlete TS9. This athlete reported a fluctuating trend in sport practice load, peaking at weeks 6 and 7, perhaps not allowing enough taper by the end of the treatment period. Training load peaked at week 2 and decreased over the eight weeks with a small rise at week 6 before it dropped of sharply, due to incomplete training sessions at weeks 7 and 8. DOMS peaked at week 3, after the perceived heavy training load at week 2 and showed a steady decline over the treatment period. This athlete stayed injury free over the eight-week training period. However, in general, this athlete rated DOMS very high during the entire treatment period as compared to the other athlete's ratings. Sleep quality was at its worst at week 4 and week 8. Stress levels increased steadily over the first 6 weeks with a decrease at weeks 7 and 8, which is a good sign. Fatigue was up and down over the 8 weeks showing no visible pattern.

Perhaps poor sleep quality towards the end of the treatment period impacted the performance results on the anaerobic power test for this athlete. Overall, this athlete did not appear to adapt to the training program as no trend in decline of adaptation indicators were present.

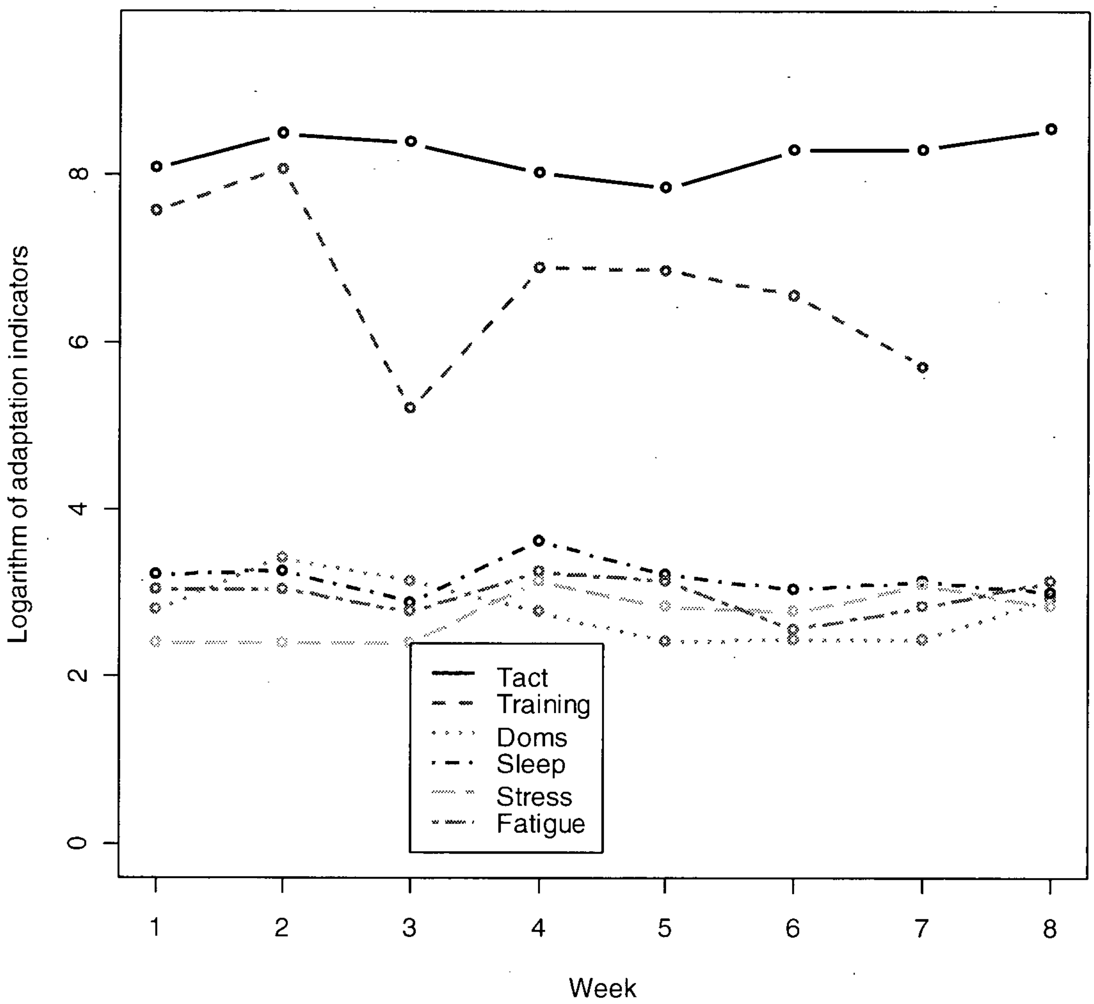
Treatment Subject 10 (TS10).

This athlete completed of 6 of 7 Monday lifting session, 6 of 6 Tuesday agility and plyometric sessions, 7 of 8 Thursday complex training and 5 of 5 Friday anaerobic conditioning sessions. Vertical jump scores for TS10 improved up to week 5 by 1.27 cm, but did not show any further improvements by week 9. Agility actually worsened over the treatment period for this athlete, showing a decline of .28 seconds at week 5 and an overall decline of .17 seconds at week 9. Anaerobic power scores, on the other hand, showed steady improvement over time for this athlete. At week 5, her score improved by 3.75 and by week 9, her overall improvement was 7.48 seconds, third best on the team. This athlete rated anaerobic conditioning sessions as 8 or 9 of 10 on the RPE scale consistently each week, which may mean she did put forth her best efforts during those work-outs and therefore saw the biggest gains in that performance indicator. Lifting sessions on Mondays were somewhat adhered to, but rated as 5 or 6 of 10 on RPE scale, indicating this athlete might not be pushing herself in the weightroom. Thursday, where complexes were used to improve explosive power, were adhered to, but also rated low on the RPE scale.

Figure 18 represents athlete TS10. This athlete reported fluctuations in sport practice load over the eight weeks with no visible trend. Training load, however, did decrease over time, with its highest point at week 2. DOMS decreased steadily over the 8 weeks, with its highest values in weeks 1 to 3. Sleep quality worsened up until week

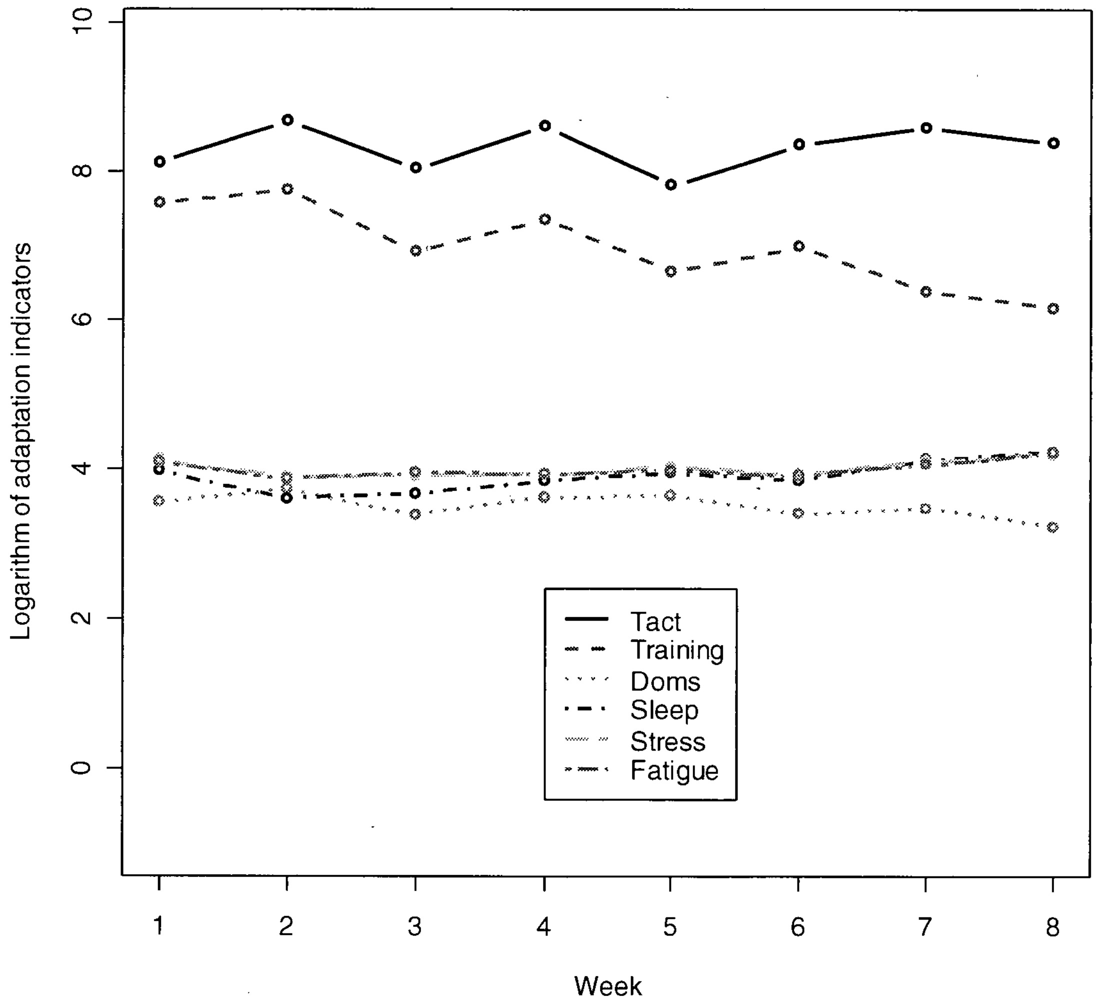
5, where it improved slightly for the next 3 weeks. Stress levels increased and peaked at week 5. Fatigue also peaked at week 5 and fluctuated over the last 3 weeks.

Figure 9 Trend in different adaptation indicators for TS1



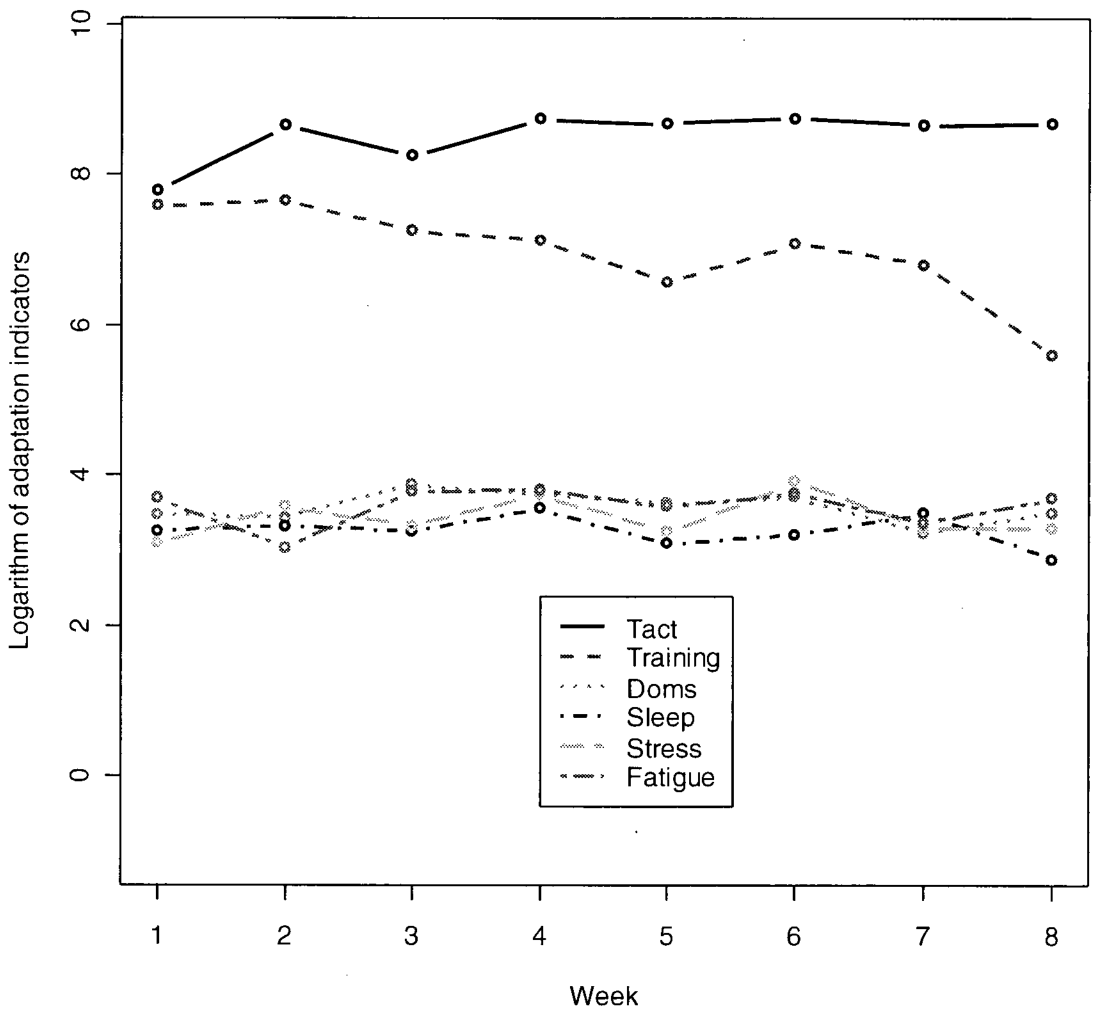
Week	Tech/Tact	Training	DOMS	Sleep	Stress	Fatigue
1	3195	1925	16.5	25	11	21
2	4815	3165	30.5	26	11	21
3	4365	180	23	18	11	16
4	3000	970	16	37	23	26
5	2515	945	11.2	25	17	23
6	3990	700	11.5	21	16	13
7	4020	300	11.5	23	22	17
8	5145	No training	19	20	17	23

Figure 10. Trend in different adaptation indicators for TS2



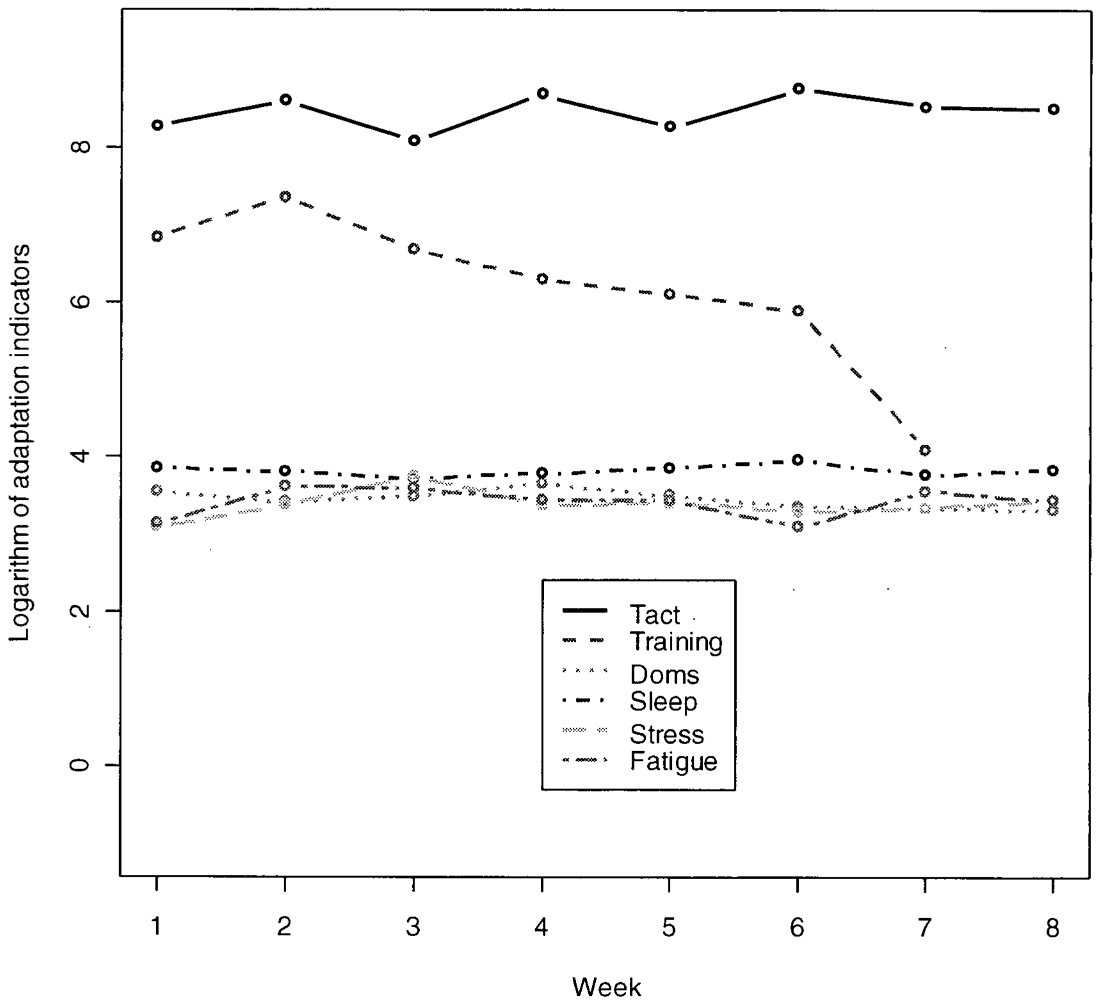
Week	Tech/Tact	Training	DOMS	Sleep	Stress	Fatigue
1	3285	1950	35.2	54	62	60
2	5760	2300	42	37	49	48
3	3060	1020	29.6	39	50	52
4	5430	1560	37.5	47	51	51
5	2460	780	38.7	52	56	54
6	4245	1080	29.7	47	51	50
7	5280	600	32.3	62	61	58
8	4365	480	25.2	69	67	68

Figure 11. Trend in different adaptation indicators for TS3



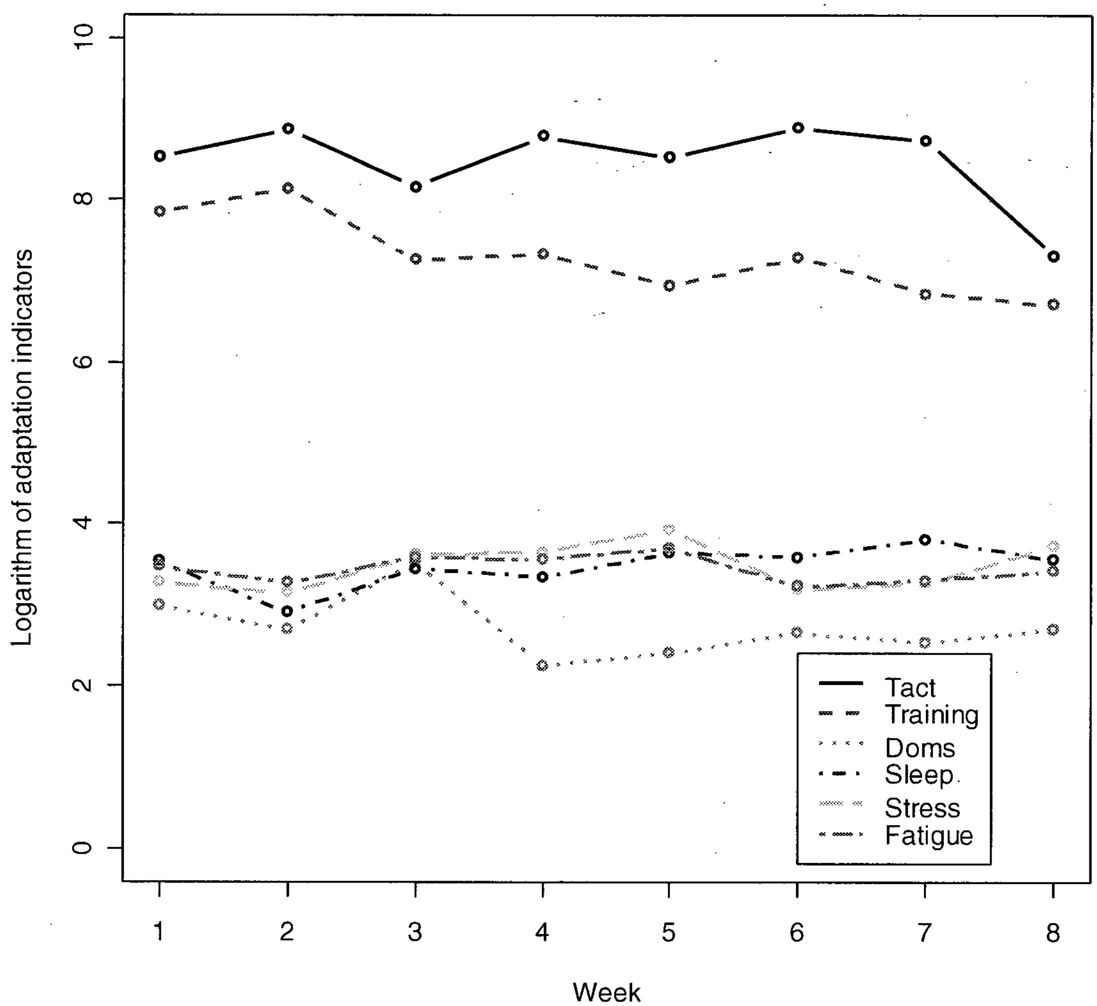
Week	Tech/Tact	Training	DOMS	Sleep	Stress	Fatigue
1	2400	1980	32.5	26	22	40
2	5670	2115	31.3	28	36	21
3	3840	1425	48.3	26	28	44
4	6210	1245	42.8	35	42	45
5	5870	720	37.7	22	26	36
6	6270	1190	40.9	25	50	43
7	5730	900	25.5	33	27	29
8	5850	270	33.2	18	27	40

Figure 12. Trend in different adaptation indicators for TS4



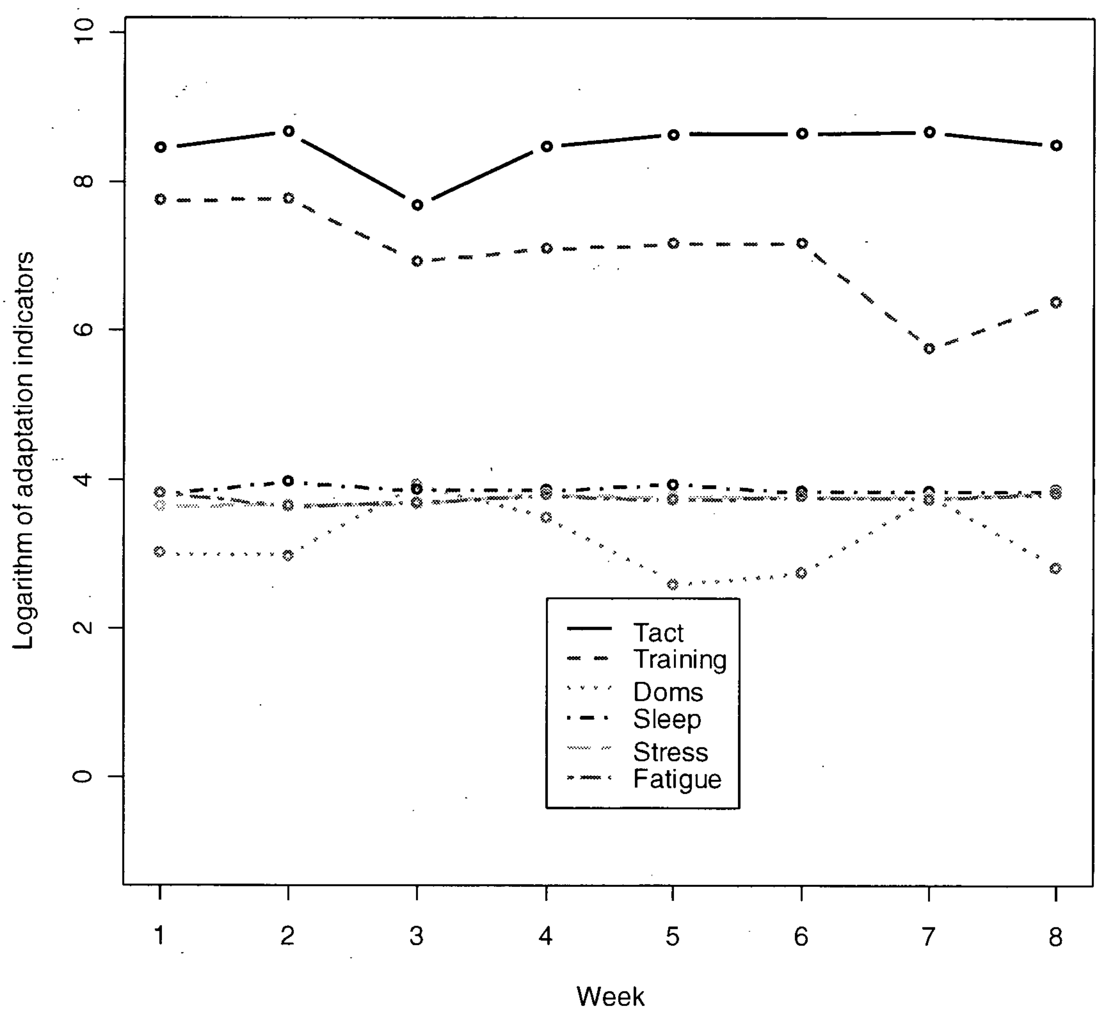
Week	Tech/Tact	Training	DOMS	Sleep	Stress	Fatigue
1	3915	940	34.6	47	22	23
2	5610	1580	30.3	45	29	37
3	3225	810	32.7	41	42	36
4	6035	540	38.8	44	29	31
5	3935	450	33	47	30	31
6	6435	360	28.6	52	27	22
7	5145	60	27.8	43	28	35
8	4995	No score	27.2	46	31	31

Figure 13. Trend in different adaptation indicators for TS5



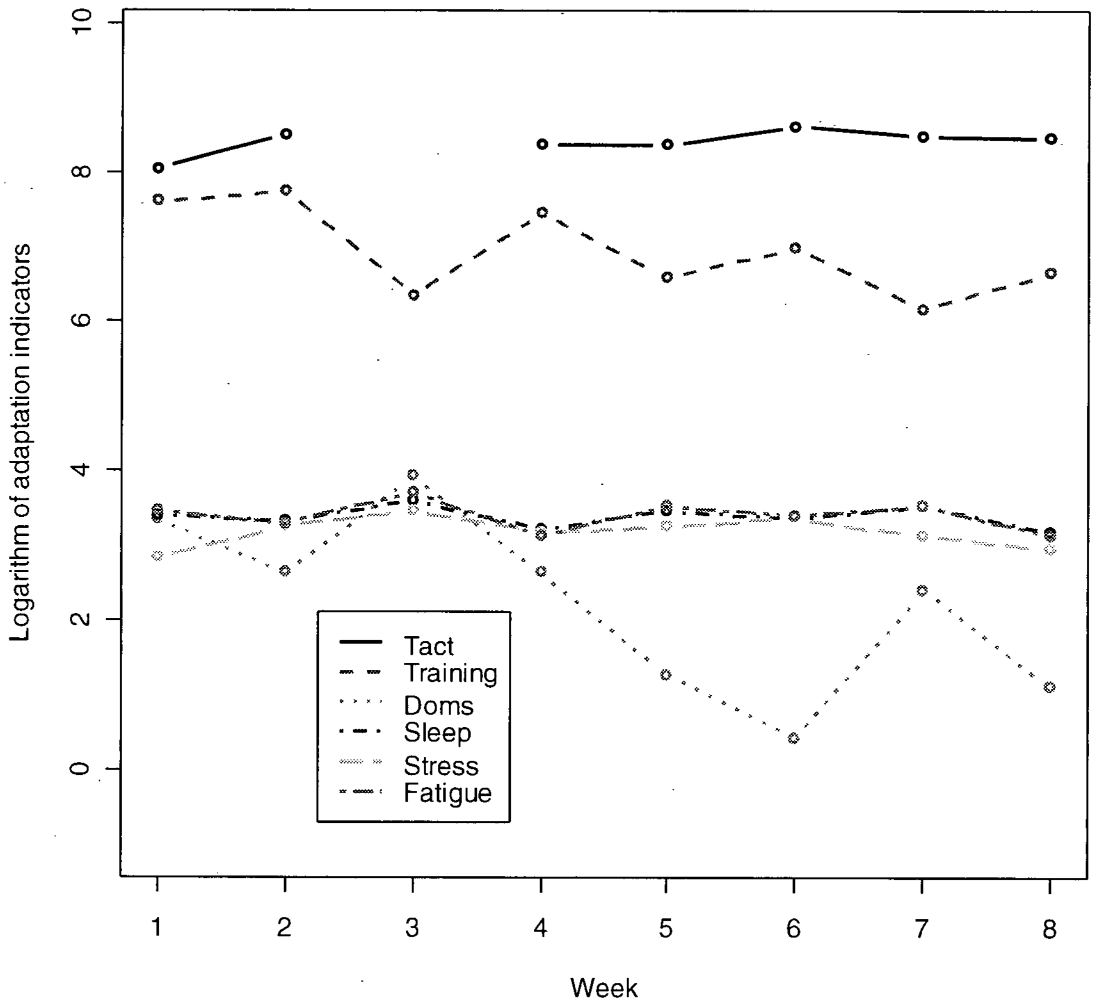
Week	Tech/Tact	Training	DOMS	Sleep	Stress	Fatigue
1	4995	2555	19.7	34	26	32
2	7035	3410	14.7	18	23	26
3	3480	1425	33.5	31	37	36
4	6445	1530	9.5	28	38	35
5	4945	1035	11.1	38	51	40
6	7155	1460	14.2	36	24	25
7	6175	935	12.5	45	26	27
8	1500	815	14.8	35	41	30

Figure 14. Trend in different adaptation indicators for TS6



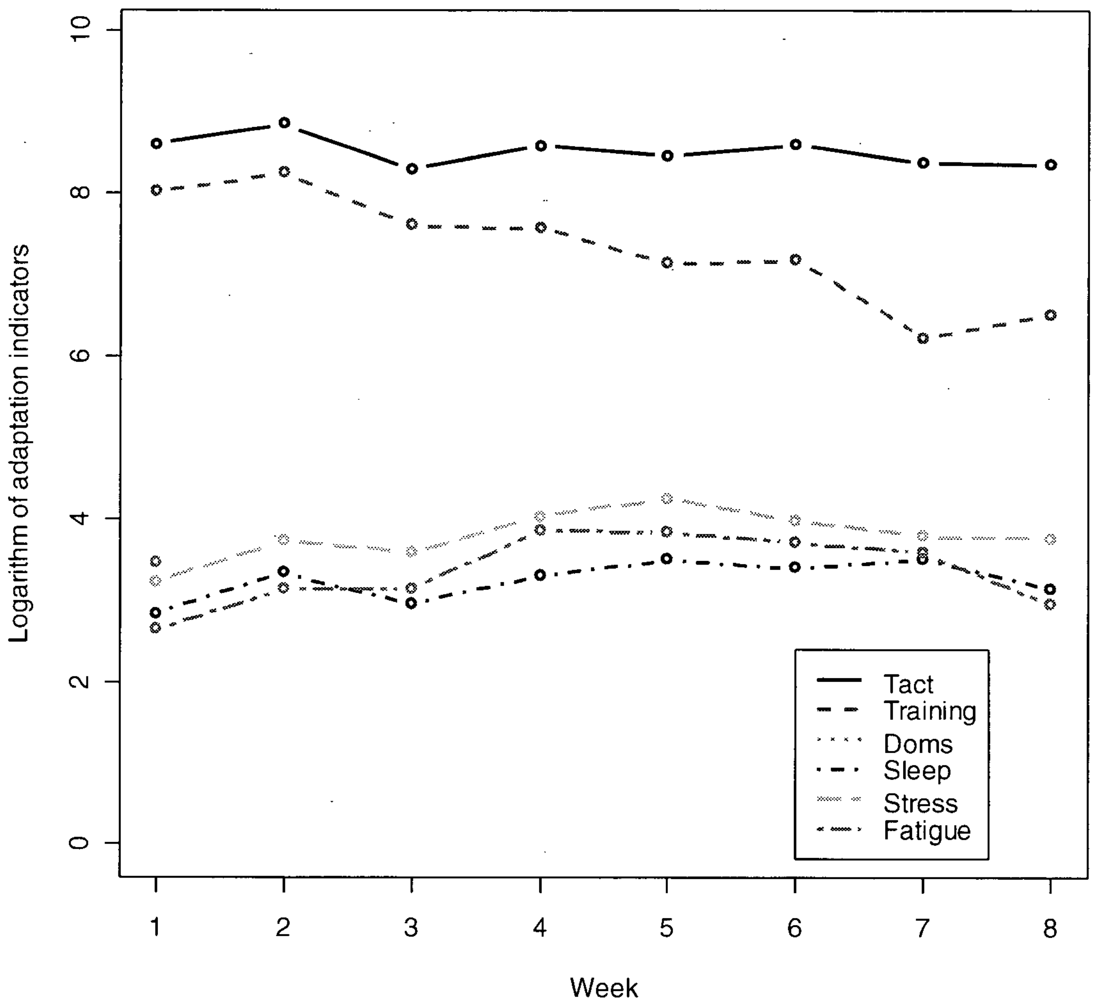
Week	Tech/Tact	Training	DOMS	Sleep	Stress	Fatigue
1	4680	2310	20.1	45	38	45
2	5760	2375	19.6	53	39	38
3	2175	1020	50.8	47	39	40
4	4800	1215	32.7	47	45	44
5	5620	1290	13.4	51	43	41.5
6	5730	1290	15.6	46	43	43
7	5845	320	43.6	46	43	42
8	4905	600	16.8	47	46	45

Figure 15. Trend in different adaptation indicators for TS7



Week	Tech/Tact	Training	DOMS	Sleep	Stress	Fatigue
1	3105	2005	28.5	30	17	32
2	4920	2293	14	28	26	27
3	Injured	570	51	37	32	41
4	4320	1730	14	25	24	23
5	4270	720	3.5	32	26	34
6	5566	1085	1.5	29	29	30
7	4793	480	11	34	23	34
8	4683	770	3	24	19	23

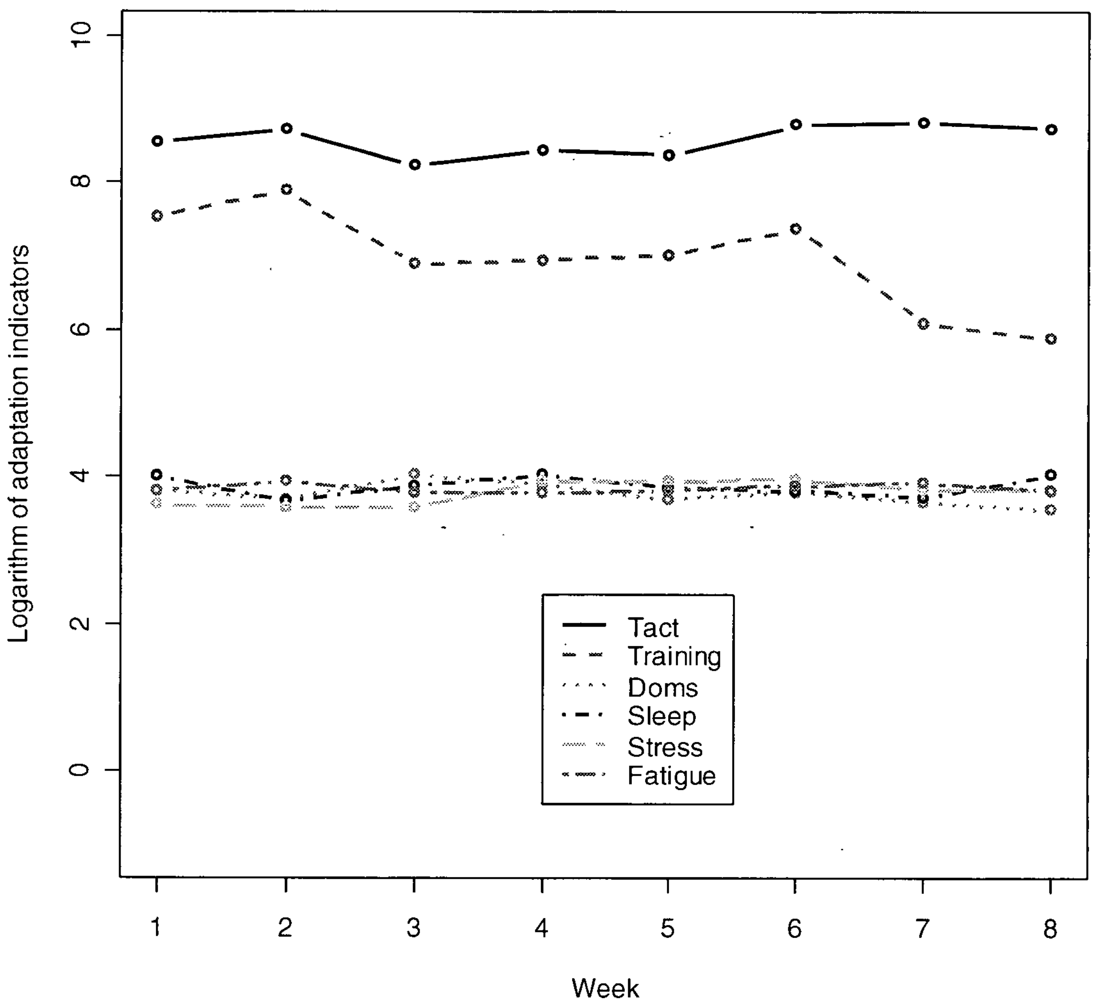
Figure 16. Trend in different adaptation indicators for TS8



Week	Tech/Tact	Training	DOMS	Sleep	Stress	Fatigue
1	5445	3070	32.2	17	25	14
2	7005	3800	0	28	42	23
3	4005	2014	0	19	36	23
4	5355	1960	0	27	56	47
5	4680	1260	0	33	70	46
6	5461	1310	0	30	53	41
7	4307	510	0	33	44	36
8	4270	675	0	23	43	19

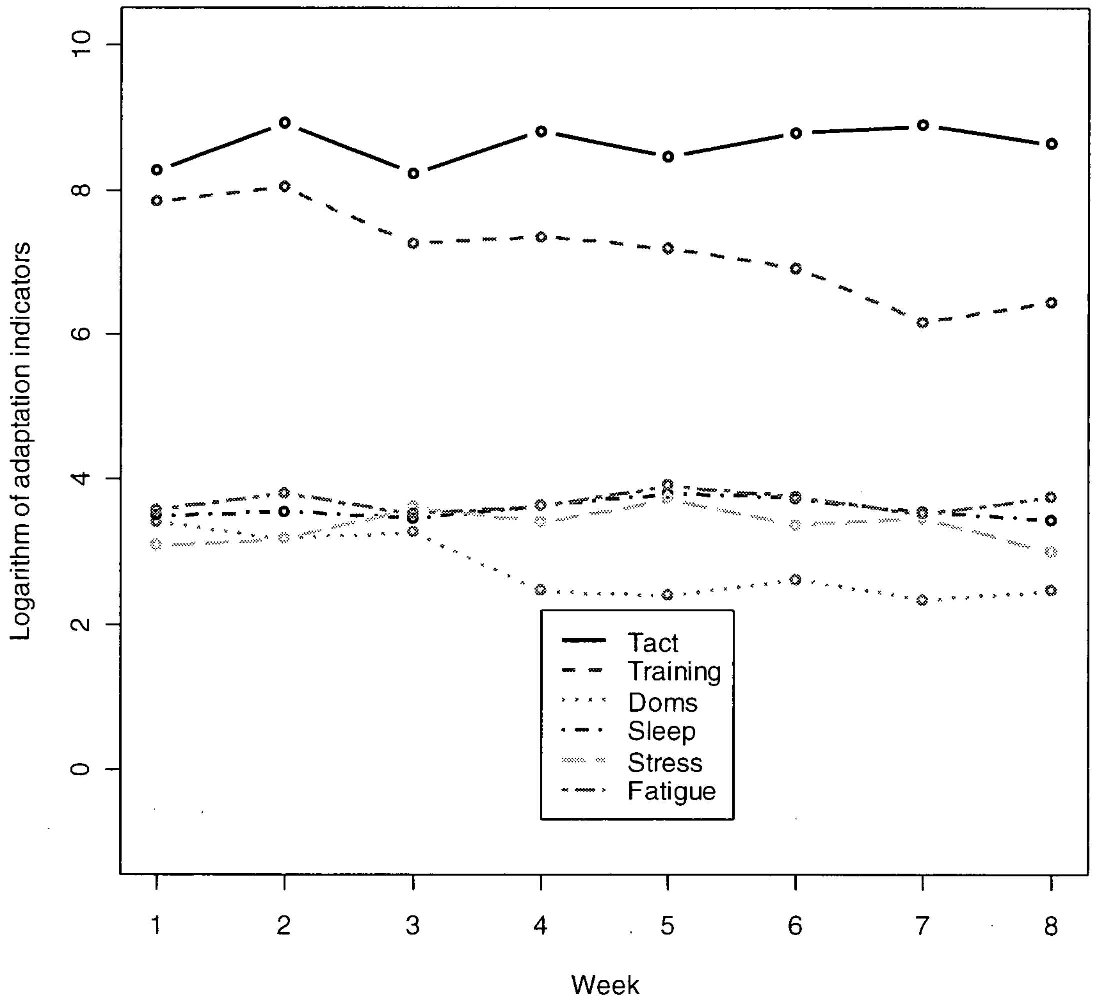
*note, this athlete rated DOMS as zero for weeks 2-8, there are no data points

Figure 17. Trend in different adaptation indicators for TS9



Week	Tech/Tact	Training	DOMS	Sleep	Stress	Fatigue
1	5100	1850	45.1	55	37	45
2	6165	2670	40.1	39	36	51
3	3750	990	56.2	48	36	44
4	4628	1040	48.9	56	51	44
5	4335	1110	40.1	47	51	45
6	6533	1600	44.2	45	52	48
7	6745	440	38.4	41	46	50
8	6230	360	34.8	56	46	45

Figure 18. Trend in different adaptation indicators for TS10



Week	Tech/Tact	Training	DOMS	Sleep	Stress	Fatigue
1	3915	2510	30.6	33	22	36
2	7450	3130	24.2	35	24	45
3	3765	1400	26.3	32	37	34
4	6705	1545	11.8	38	30	38
5	4760	1315	11	45	42	50
6	6560	995	13.7	42	29	43
7	7260	480	10.4	35	32	34
8	5630	625	11.9	31	20	43

Strength and Conditioning Program Features

Determining an effective and efficient method of performance enhancement for basketball that can be tested by objective research has been the focus of this project. First, it is paramount that athlete's be assessed in measures that relate directly to the physical demands of their sport prior to any performance enhancement program. Tests of lower body power, leg speed or agility and anaerobic fitness are most valuable for basketball athletes. This pre-season program was also be structured around sport practice and game schedules and tapered for two weeks prior to the start of the competitive season. Tapering should consist of a decrease in volume of resistance training sets and training days, 3 days reduced to two days and 3 or 4 sets reduced to 2 sets, a decrease in plyometrics volume as expressed by foot contacts (<200), and elimination of specific bioenergetic training outside of drills involving the dominant energy systems in sport practices.

During the pre-season program, there must be enough recovery prescribed so the athlete's will adapt to the training stimulus. This was accomplished by using a periodized training plan. In the program, the number of sets, repetitions, exercises, amount of resistance used, the rest between sets or exercises, the type and speed of muscle contractions and the training frequency were manipulated. Strength training was performed 2-3 times per week, using multi-joint power exercises and Olympic lifts. Prescription varied in volume and intensity over the training microcycle, using an undulating model (Rhea, Ball, Phillips &Burkett, 2002), where one day is heavy, one day is medium and one day is light. This program recommended a heavy day on Monday, a medium day on Thursday and a light day on Saturday. Sunday was always a rest day and this appeared to be necessary for the athletes both physically and mentally. Plyometrics were followed twice per week in the pre-season, with a minimum of 48 hours separating work-outs. It is inconclusive whether agility training, employing plyometric movement patterns that involve an increasing demand for change of direction over the 8 weeks enhances leg speed of basketball athletes at this elite level. Agility,or, more specifically, change of direction speed, may have been enhanced by practicing and playing the sport itself, which could serve as an efficient means of targeting that performance indicator. Athletes that are fatigued, however, do display reductions in agility performance, so perhaps an agility assessment more frequently during the pre-season phase of training and practice should be administered weekly to monitor adaptation to the training stimulus.

The key to a successful anaerobic power program is carefully prescribed volume and intensity, not exceeding six sets of each drill per session. It was found that 30 and 45 second drill times were effective for improving this performance indicator for basketball athletes and the work to rest interval be reduced over time from 1:3 to 1:1.

Recommendations for Program Improvement

The strength and conditioning work-outs that were most adhered to by the athletes were the ones that were supervised. Also, work-out intensity was were it needed to be when the investigator was present. It was assumed the athletes who did their lifting and complex training sessions on their own were challenging themselves physically. A change that could be made to the program would be team lifting session to ensure adherence and work ethic.

Agility is a parameter that needs to be prescribed and evaluated more closely. There is very little research on agility prescription; all that is known scientifically is that straight sprinting enhances speed in a straight line, not complex agility maneuvers

(Young et al., 2001). Although leg power and agility are not statistically correlated (Pauole et al., 2000), it would be interesting to see if plyometric training alone would improve agility performance as both type of exercises are very similar in that they both capitalize on stored elastic energy and the stretch-shortening cycle. However, true agility in the sport context does require the athlete to read and react to an opponent and a predictable test, like the T-test may not be as specific as it should be. Furthermore, this program incorporated agility drills only once per week, due to time and limited facilities. An agility program, followed more than once per week should be evaluated.

Future Directions

Future studies are needed concerning all outcomes of periodized training, compared to non-periodized training or no training, especially concerning motor performance changes such as vertical jumping ability and sport-specific agility in the long-term (12 weeks to 4 years) for basketball. An eight week period merely investigates the effects of one training phase, on a group of athletes. It is not long enough to study the impact of how undulating periodization may impact results in performance over an entire varsity career. Although the treatment group was relatively homogeneous in terms of training age and experience, it would interesting to measure results of this type of program on a group of athletes with a decade of training experience, such as those on the national team, or increase the number of subjects to better represent the population. Also, control groups must be identically matched in order to statistically analyse all results and increasing the number of subjects involved in training studies would increase their validity.

Furthermore, additional research is also needed to determine performance variability between positions, so exercise prescription can be based on these considerations as well. Currently, programs are designed for the entire team and followed as a team, mostly due to lack of resources. Also studies should focus on using actual on-court basketball performance as a means of validating the strength and conditioning program as strength and conditioning variables may not always relate directly to being a successful basketball player. For example, if the athlete is normally required to jump using a run up, or if they have to hold a basketball, traditional vertical jump testing may not reflect their true capabilities in their sport environment. Also, there have been no studies reporting whether it is better to train for vertical power by emphasizing single leg take-offs in a sport like basketball where cutting and jumping movements are frequently unilateral. An investigation of leg dominance could help identify risk for injury as well.

Research identifying an objective means of identifying deficits in athlete jumping ability would also help investigators evaluate the effectiveness of their programs in improving explosive power. It would be easier to interpret post-treatment testing results on athletes that were pre-screened for these impacting factors: maximal strength level, stretch-shortening ability of the muscle, muscle fiber typing and jumping skill.

Research examining potential overtraining markers in anaerobic athletes in almost non-existent, and the limitations by financial considerations of most teams does not allow for sophisticated laboratory analysis of biochemical markers such as creatine phosphokinase, hypothalamic dysfunction, muscle glycogen content and testosterone/cortisol ratios. Therefore, an athlete log book is a good solution to these limitations, but the predictive ability of the athlete log should be tested statistically. The present study quantified training loads and monitored performances after the athletes completed them. A predictive training-performance model would have huge utility in future research as suggested by Taha and Thomas (2003 pp. 1072). The end result would be the ability to detect unusual patterns of maladaptation as well as see which performance indictors have the greatest impact on basketball performance.

In terms of training studies and assessing the effectiveness of exercise prescription, it is recommended that experienced athletes must always be used, volume and intensity must be equated for every session and the outcome measures be clearly defined, rated and monitored as frequently as possible. Sport scientists should be encourage to formulate research designs that transfer directly into the practical setting with clear guidelines, rationale and limited room for subjective interpretation.

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Appendix A.
Review of the Literature: The Pre-Season Training Plan

Most training studies to date have measured the physiological and biochemical responses of the human subject to endurance training programs and have paid less attention to the extent to which human exercise performance is altered in non-endurance programs. The specific physiological adaptations, which explain training induced changes in athletic performance, have yet to be examined comprehensively (Fleck, 1999).

In fact, the majority of research studies, examining the effectiveness of periodized training, have focused on direct strength and power gains via the manipulation of intensity and volume, rather than the effect the program has on sport performance. Furthermore, most profile studies have tended to focus on performance of swimming, cycling, wrestling, skiing and running (Lamonte, 1999), which are all individual sports. These individual sports have simply been profiled more frequently due to the ease of evaluating these athletes in the lab setting (Lamonte, 1999). More research is therefore needed to evaluate training responses of team sport athlete populations.

Recently, more studies have been recommended on female's response to periodized training protocols (Dudley & Fleck, 1987) and that care be taken to identify the specific physical requirements of the team sport of basketball (Lamonte, 1999). Since these suggestions have been identified in the literature, implementation and documentation of specific training, regarding workloads, periodization and corresponding performance results is needed. Recently, physical and physiological profiles have been reported (Lamonte, 1999), which will lend valuable information to compare sample groups to the population. Past training studies conducted on female basketball athletes has been focused on collective team profiles versus individual physical profiles and individual adaptation to the training program (Lamonte, 1999), thus illustrating the need to evaluate the training response for each athlete involved in a team sport.

The period prior to the official starting date of the competitive season is termed the pre-season conditioning period. During this period, which typically lasts 8 – 10 weeks, the goal is to achieve maximal physical performance. The predominant performance requirement for success in a large number of athletic skills is explosive power (Newton & Kraemer, 1994). Therefore, the training prescription for basketball athletes during this period often focuses on converting the gains made in the maximum strength phase into sport-specific, explosive power. It is during this period when the gains of the previous phases are converted into specific movement speeds and patterns necessary for elite sport performance.

Explosive movements are required in basketball and are typically performed at high speeds. In fact this explosiveness may be the most important parameter an elite athlete possesses. Many investigations have shown that the maximal rate of force development is a very significant factor in explosive performance (Newton & Kraemer, 1994). For years, information from the field of sport science has led to a practical interpretation at the coaching level that a periodized, progressive, strength-training program incorporating general strength training, stabilization, balance, Olympic Lifting, and plyometrics as well as speed and agility drills would achieve optimal explosive performance.

The bioenergetics of basketball is broken down into anaerobic power (35%) and anaerobic capacity (25%), with less reliance upon aerobic energy release (20% aerobic glycolysis, 20% fat oxidation) (Brooks, Fahey & White, 1996). Therefore, anaerobic performance measures are most useful in assessing the physical attributes of basketball athletes. No single test, however, is a universal indicator or anaerobic power and capacity. Therefore, a cross section of validated and reliable field and laboratory tests can be used to evaluate the training response and physical capabilities of basketball athletes. Coaches can use these assessments as a means of recruiting players and evaluating the athlete's training program (Lamonte, 1999).

Observation of performance results and their relationship to training is of particular interest to the athlete who has been training and competing at a high level prior to the addition of, or more specific, explosive power training. Further research will have meaningful application at the coaching level and enhance results on the performance level of competitive basketball athletes.

Program Design

The long-term plan of a training program is termed periodization. It is a global concept encompassing periods (phases) of stress and adaptation with the goal being improvement in all physical performance parameters and optimal readiness for competition (Fleck, 1999). Training programs are structured according to the laws of periodization. It is optimal to vary the training program (mesocycle) at regular time intervals in an attempt to bring about optimal gains in strength, power, motor performance, and/or muscle hypertrophy (Fleck, 1999). The classic form of linear periodization divides a typical strength training program into different cycles, gradually increasing the training intensity while decreasing training volume within and between cycles (Rhea et al, 2002). A less used form of periodization, called undulating periodization is characterized by more frequent alterations of volume and intensity within a cycle itself. Rather than making changes over months, or mesocycles, changes in the training variables are made on a weekly or even daily basis. Intensity can be decreased at times to provide "light" sessions. Advocates of this technique believe that the variations in intensity help prevent overtraining syndrome (OTS), especially during the dense schedule of training sessions and practices everyday. Rhea et al, compared a linear periodization model to a daily undulating model and found the latter to elicit higher strength gains. It is hypothesized that daily undulating periodization places higher demands on the neuromuscular system, requiring further adaptations from this system and thus greater gains. Stone et al, (1997) suggest that microcycle variations are crucial for the advanced athlete because they insure the avoidance of overtraining and also maximize total work accomplished.

Training Prescription Principles

Training programs are designed in accordance with three basic principles of training: individualization, overload and specificity (Beachle & Earle, 2000) A sports analysis of basketball revealed that these athletes need to be moderately strong, powerful, have quick, explosive bursts of speed and endurance to repeat these bursts throughout the course of a practice or game (Adams, O'Shea & Climstein, 1992 and Blakely & Southard, 1987).

Individualization of exercise programming means that it is tailored to an individual's needs, athletic ability, maturity, fitness, experience with training and most importantly, his or her goals (Lundin, 1986). Baseline testing should be performed to optimize progression and evaluate the success of the imposed program (Kraemer, 2003). Improvements in all physical parameters: strength, power, endurance, flexibility and body composition are all determinant on how realistic and specific the training program is. Genetic endowment paired with an individual's pre-training physical status will often determine the effectiveness of a training program (Kraemer, 2003). Training programs must also evolve as goals are achieved and should be adjusted for different rates of achievement.

Progressive overload refers to the need for a greater, or more complex stimulus for continued adaptation and improved force production. Stress studies, conducted by Hans Selye in the early 1960's developed the basic concepts of the general adaptation syndrome. A new stress creates an alarm reaction, adaptation to a given stressor can be tolerated for a given period of time and the stressor must be removed or altered to prevent maladaptation. Progressive resistance exercise is necessary for increasing muscle strength. Overload can be accomplished in several ways: increasing the number of sets, increasing the load, increasing the contraction velocity, decreasing rest periods between sets, introducing complexes and so on. Athletes must progress steadily and gradually with training load in sync with their ability to tolerate the training load. The purpose of training is to place a greater demand on the athlete, so they adapt and consequently improve. Athletes however, only improve during recovery; coaches must plan and prepare equally for recovery as they do any other aspects of the athlete's training.

The specificity principle implies that in order to improve performance, neuromuscular and metabolic systems utilized in the given activity must be overloaded in training. Specificity also has a major influence on the training adaptations and their transfer to the sport environment. Exercise prescription should be related to the muscle recruitment patterns involved, the speed of execution, the range of motion, the particular muscle groups involved, the bioenergetics and the intensity and volume of training (Kraemer, 2003). Training programs must be designed such that muscles are stimulated relating to the above variables. Since movements occur in all three planes of motion, standard Olympic lifts and sport-specific variations of these lifts as well as unilateral, multi-joint exercises should be selected. Stabilization exercises should be prescribed as well to lessen the chances of injury; these will involve one limb at a time and the use of unstable base devices. Exercise order is carefully considered, all training sessions beginning with higher loads and more complex lifts.

Chronic Program Variables

Volume is the total number of repetitions performed and quantified as sets multiplied by reps (Marsit, 1994). In plyometric training, volume is tallied by the number of foot contacts. In anaerobic training, it is quantified by the length of the drill or interval. In aerobic training, it is the length of the session at the target heart rate zone.

Intensity can be expressed as a percentage of peak power or one rep maximum. It can also be expressed as a percentage of one's maximum heart rate or as one's rating of perceived exertion during the training session or drill (Baechle & Earle, 2000).

Acute Program Variables

Exercise should be matched to the biomechanical characteristics of the sports-related movements and skills and should include structural closed-kinetic chain, multi-joint exercises, exercises in all planes of movement (saggital, frontal and transverse). It should also target all of the major muscle groups working from the core the body to the periphery. The use of concentric, eccentric and isometric muscle actions is also critical. The sequence of exercises has a dramatic effect on fatigue felt during the work-out. Exercises that require larger and several muscle groups allows for the use of heavier weights if performed early in the work-out. It is based on individual training goals and is dependant on bioenergetics and the amount of fatigue induced during the training session (Kraemer, 2003).

Sets are part of the volume equation. Evidence suggests that multiple set systems work best for the development of strength and local muscular endurance (Kraemer, 2003). Volume is a more important variable than sets alone. Volumes can be adjusted up or down depending on the phase of training an athlete is in.

The amount of rest between training sessions depends on the recovery ability of the individual and the demands of other physical activities he or she may be participating in outside of the lifting program. Traditionally, three work-outs per week were found to be adequate for recovery (Kraemer et al, 1998). Rest periods between sets, will determine how much ATP/CP energy source is re-synthesized and how high lactic acid concentrations become in the muscles and blood (Kraemer, 2003). Lactate contributes to muscle fatigue, loss of coordination and decreased force production. By altering rest periods, influences on metabolic, hormonal and cardiovascular responses to an acute bout of exercise and each subsequent set are affected. Careful manipulation of rest periods is key in the prescription process.

Coaches have also employed the technique of tapering, which is a gradual reduction in training load. It is unknown whether tapering provides sufficient recovery of the athlete to reverse the effects of heavy training and achieve peak performance

(Hooper, MacKinnon, Howard, Gordon & Bachman, 1995). Also, markers used to monitor daily recovery of the athlete during the taper do not appear to have been researched in great detail (Hooper et al, 1995).

Training Components for Basketball

According to Marsit (1994, pp.70), "two goals identified in a basketball conditioning program include improving explosive strength of the legs and hips, which will result in higher vertical jumps and to improve conditioning of the athlete specific to basketball." Specific training can enhance power and velocity of muscle contraction to improve jumping performance (Klinzing, 1991).

Al Vermeil, former strength and conditioning coach to the Chicago Bulls states "the training components for basketball include: 1. Work capacity, which is the ability to perform work over a period of time, and the ability to recover from this work. 2. Strength: the ability to exert force 3. Speed-strength: the ability to exert strength quickly and 4. Speed: the ability to move the body or part of the body through a range of motion in the shortest possible time."

The Pre-Season Training Period

During the pre-season training period the coaching staff and the athletes will be collaborating most frequently as the competition season approaches. The off-season, if successful, should have laid the foundation for base strength and explosive strength levels (Marsit, 1994). Therefore, the two focal points for the pre-season phase should be to improve explosive strength and power and improve sport-specific conditioning (Marsit, 1994).

The weight training volume should be decreased to account for the increase in practice time and running volume. Plyometric training is also incorporated to improve explosive power. The purpose of the sport-specific conditioning portion of the pre-season is to enhance the anaerobic glycolytic and ATP-PC systems. In order to train these pathways, drills should last approximately 10 seconds to 2 minutes with a 1:3 work to rest ratio (Marsit, 1994; Caprara, 1994). Running patterns used in agility training and anaerobic training should also be specific to the on-court movements (Marsit, 1994).

Training Methods: Power Training

Heavy loads, using Olympic style lifts have an explosive, accelerative velocity profile, making them more specific than traditional resistance training exercises. Although heavy resistance training increases maximum strength, the highest point of the force time curve, this type of training does not improve power significantly (Lamonte, 1999). It has been suggested (Hakkinen, Komi & Allen, 1985) that training should be focused on increasing optimum strength rather than maximal strength as optimum strength training increases performance whilst maximum strength increases force only. Studies on isokinetic testing and training methods have found that strength increases are specific to the velocity at which one trains (Hakkinen & Komi, 1986). This would provide a basis for resistance training performed at high speeds if explosive power is the goal.

In many athletic movements, only a fraction of a second is available to develop the greatest possible force. The actual movement time during explosive activities is typically less than 300 ms and most of the force increases cannot be realized over such a short time. Maximal power is produced at intermediate velocities of movement, that is, at approximately 30% of shortening velocity (Lamonte, 1999). Power performance is also impacted by the interaction between agonist, antagonist and synergist muscles involved in the joint movements. Therefore, specific training movements will reduce the co-contraction of antagonists and increase the coordination of agonist and synergist activity (Chimera, Swanik, Swanik & Straub, 2004).

Since the rate of force development (RFD) can be the limiting factor to success. A related training technique is velocity-specific strength training. The neuromuscular system has a high adaptive capacity and the adaptation process is very specific. Therefore, training with high velocity movements increases this high velocity strength relatively more than low velocity strength. This adaptation could be due to an increase in maximal shortening velocity of the muscle and the rate of the onset of motor unit activation (Hakkinen & Komi, 1985) as well as an acquired ability to increase maximum motor unit firing rates in ballistic actions.

Olympic-style lifts can be termed explosive. The clean and jerk and the snatch and variations of these exercises, must be performed quickly to be successful. Since this speed of movement must be maintained, mechanical power outputs are high (Hedrick, 1996). The "pull" on the clean or snatch is 4-5 times faster than that on the deadlift or squat and 11-15 times greater than the bench press. It is agreed that the best technique for executing these lifts is best described as vertical jumping while holding a barbell (Hedrick, 1996). It has been recommended that athletes who need to improve their jumping ability should include the snatch and the clean in their strength training program (Hedrick, 1996). There are significant similarities in lower extremity and torso movements during the propulsion phase of a vertical jump and the second pull of the snatch or clean lift. The preparatory position for these lifts are very similar to that of a vertical jump as well with respect to angles at the knee, hip and ankle. Time curves through the final extension range are also comparable.

Training Methods: Plyometrics

Plyometrics have long been considered to enhance both the mechanics of performance in vertical jumping as well as addressing the need to improve rate of force development (Wagner & Kocak, 1997). It has been proposed as a training mode designed to enhance movement patterns that are used in motor activities such a sprinting and jumping (Potteiger, Lockwood, Haub, Dolezai, Khalid, Schroeder & Zebas, 1999). Plyometric activities involve a counter movement during which the muscles involved are first stretched rapidly and then shortened to accelerate the body upwards. With the application of the stretch-shortening cycle (SSC) providing elastic energy stored in the series elastic components it is common belief that the athlete improves the potential for force production. The improvement comes from a counter movement prior to concentric contraction. The muscle is stretched while it is active leading to a greater concentric contraction than could be generated from a static position. The ability of the muscle to rehearse and adapt to this stretch-shortening cycle will lead to the generation of more power. In has been established, through several research studies that plyometric training is effective for improving power output and vertical jump performance (Potteiger et al., 1999).

Plyometrics may also facilitate beneficial adaptations in the sensorimotor system that enhance dynamic restraint mechanisms and correct faulty jumping or cutting mechanics (Chimera et al, 2004). The dynamic restraint system relies both on feedforward and feedback motor control to anticipate and adjust to joint movements or loads. Functional training techniques with repetitive jumping and deceleration activities may create plastic neurologic adaptations to motor programs that improve coordination for both performance and dynamic restraint (Chimera et al, 2004). It has been suggested that muscular power gains after plyometric training is attributed to neural adaptations, rather than morphological changes. Thus, plyometric training may enhance neuromuscular function and prevent joint injuries by improving joint stability (Chimera et al, 2004). Motion and forceplate data after plyometric training revealed that trained female athletes had lower abduction and adduction moments at the knee and lower landing forces when compared to untrained males (Chimera et al, 2004). This increased muscle activity will augment muscle-stiffness properties, so that joint loads are absorbed within the tendomuscular unit rather than transmitted through articular structures (Chimera et al, 2004). Plyometric training has also been demonstrated to both increase hamstrings to quadriceps ratio and to decrease the incidence of ACL injuries in female athletes (Wilkerson, 2004). Finally, research on patellar and achilles tendonopathy, a common basketball injury, have been prevented through means of eccentric strength and plyometric training (Khan, Cook, Taunton & Bonar, 2000).

Eccentric strength can be the limiting factor especially in more complex, high volume and high intensity plyometric training. Without sufficient levels of eccentric strength, in the knee extensors, switching from eccentric to concentric work becomes very inefficient. The specific goal before any emphasis of plyometric training should be to increase the level of eccentric strength of the athlete. This can be accomplished with a well-designed resistance training program.

Training Methods: Complex Training

Studies in the past have demonstrated an enhancement of motor performance associated with plyometric training, weight training and the combination of both in methods termed complex training (Ebben, 2002; Hedrick, 1996). Complex training alternates biomechanical similar high load resistance training exercises with plyometrics, set for set, within the same workout (Ebben, 2002). It has been found that pre-requisite strength is necessary for complex training to be most effective and that this type of training may be best suited for those who are highly trained (Ebben, 2002). One training study (Ebben, 2002), examined the effects of a three-week complex training program with seven, division one college female basketball players. Pre and post test results revealed an improvement in the 300 m shuttle, the 1 mile run, VO2 max, the 20 yard dash, the pro agility run and the t-test, reverse leg press and back squat. However, the research design does not appear to have evaluated the effectiveness of non-complex training combinations of plyometrics and weight training or used a control group (Ebben, 2002).

It has also been found (Wilson, Newton, Murphy & Humphries, 1993) that 10 weeks of explosive jump squats at 30% 1RM increases vertical jump by 18%, versus plyometric training alone or traditional back squats alone. Further research by Berger (1963) used an explosive jump squat at 50-60% 1RM. This method improved vertical jump performance versus static training or plyometric training alone. Research, does suggest that complex training is at least equally effective, and in some cases superior, when compared to other forms of combined weight and plyometric training as evidenced by increased medicine ball throwing power, superior acute jump performance and improved vertical jump (Ebben, 2002; Adams et al., 1992). Just prior to the competition phase, more specific neural training is desirable with an emphasis on rapid force development, high contraction velocities, use of the stretch-shorten cycle and skill-specific movements (Chimera et al., 2004).

Exercise Prescription: Plyometrics

A plyometric program should begin with about 100 foot contacts and progress to about 300 jumps per work-out (Klinzing, 1991). An increase of 20 contacts per week is considered an optimal progression (Klinzing, 1991). Athletes should be monitored and coached closely during plyometric training to ensure they giving maximal efforts and minimizing the amount of time spent on the ground. The foot should make contact with the floor on the ball, unless bounding and depth jumps are executed. In that case, the heel will also make contact with the floor. Arm movement should also be coached and emphasized as vigorous upward movement (Klinzing, 1991). Rest period should also be at least one minute between sets to ensure recovery of the ATP-PC system.

Exercise Prescription: Complex Training

The rest interval between strength training and a plyometric set is an important training variable. Short rests, where a plyometric exercise immediately follows a strength exercise may take advantage of the heightened stimulation of the neuromuscular system (Ebben, 2002). However, it may not be long enough for the regeneration of the phosphagen system, which can limit power output. Ebben investigated this and found that longer recovery intervals did not show a significant improvement in power versus shorter recovery intervals, or plyometrics immediately after resistance (2002). They state that complex training may be an "efficient organizational strategy, allowing incorporation of resistance training and plyometric training in the same facility at the same time" (2002 pp. 46).

Exercise Prescription: Anaerobic Power

The activity patterns of basketball are intermittent in nature, consisting of repeated bouts of brief (<=6-second) maximal/near-maximal work interspersed with relatively short (<=60-second) moderate/low-intensity recovery periods (Glaister, 2005). Incorporating multi-directional anerobic interval training into a pre-season training program, while eliminating the focus on aerobic training aims to bioenergetics related to game performance. During a single short (5- to 6-second) sprint, adenosine triphosphate (ATP) is resynthesised predominantly from anaerobic sources (phosphocreatine [PCr] degradation and glycolysis), with a small (<10%) contribution from aerobic metabolism. During recovery, oxygen uptake (V-dotO_2) remains elevated to restore homeostasis via processes such as the replenishment of tissue oxygen stores, the resynthesis of PCr, the metabolism of lactate, and the removal of accumulated intracellular inorganic phosphate (Pi). If recovery periods are relatively short, V-dotO_2 remains elevated prior to subsequent sprints and the aerobic contribution to ATP resynthesis increases. However, if the duration of the recovery periods is insufficient to restore the metabolic environment to resting conditions, performance during successive work bouts may be compromised. Although the precise mechanisms of fatigue during multiple sprint work are difficult to elucidate, evidence points to a lack of available PCr and an accumulation of intracellular Pi as the most likely causes. Moreover, the fact that both PCr resynthesis and the removal of accumulated intracellular Pi are oxygen-dependent processes has led several authors to propose a link between aerobic fitness and fatigue during multiple sprint work. However, whilst the theoretical basis for such a relationship is compelling, corroborative research is far from substantive.

It is recommended in the pre-season that basketball conditioning drills last 10 seconds to 2 minutes of maximal effort with a work to rest ratio of one to three (Marsit, 1994). Caprara recommends a work to rest ratio of one to one or one to two, which is similar to the demands of the game. Also, it is recommended that a work-out "should not exceed 6 sets and should only be used once per week" (Caprara, 1994, pp.18).

Exercise Prescription: Agility Training

Agility is described as "a quality possessing the ability to change direction and start and stop quickly" (Young, McDowell & Scarlett, 2001). Sprinting in a straight line is a relatively closed skill in that allows an athlete to accelerate in a predictable manner, which is very common in sports such as track and field and gymnastics. In basketball, changes of direction may be initiated to either pursue or evade an opponent or react to a moving ball (Young et al., 2001). Findings suggest that straight sprinting and complex agility maneuvers have little in common and are very specific qualities an athlete must posses (Young et al., 2001). Speed and agility have little in common statistically, leading researchers to conclude that they are independent qualities (Young et al., 2001). Research conducted in 1969 reported that agility training was also superior to speed training for performance in the Illinois agility run and a zig zag run (Young et al., 2001) The authors, however, failed to qualify the training protocols, which make it difficult to infer what methods improved agility. Currently there is debate on the optimal frequency of agility training sessions and there is very little published research in the area Young suggests (Interview, 2005). "The training frequency and volume has got to depend on individual requirements." (Young, 2005). "Usually one session a week isn't enough for development of any quality but basketball drills are probably training agility without intending to." (Young, 2005). It is evident that agility training protocols and their effects on performance need to be evaluated with basketball athletes.

There are many different methods to prepare basketball athletes for competition, which are all effective to some degree if progressed and implemented appropriately. The relative effects of resistance training, plyometric training and various combinations of these methods have been well documented in the literature (Adams et al., 1992, Blakely & Southard, 1987 and Brown, Mayhew & Boleach, 1986). No studies thus far have examined these training techniques in conjunction with metabolic conditioning, sport practice and specific agility training.

Appendix B: Review of the Literature: The Adaptation Process

It is essential that we study the effects of a training program on performance and adaptation patterns of competitive athletes. The methodology of measuring the effects of a periodized pre-season plan has not been a focus of attention in the literature (Hopkins, 1991). Instead, physiological monitoring has been at the forefront of leading research. Exercise-induced decreases in force production resulting from muscle injury during training have been researched; what hasn't is a formal model of fatigue and performance variables (Taha and Thomas, 2003).

The purpose of quantifying adaptation is to systemize training prescription for anaerobic/intermittent team sports (Hopkins, 1991). Also, it is critical to investigate a means of tracking sports injuries and risk factors for overtraining syndrome (Hopkins, 1991).

The goal of basketball practice and physical conditioning is to provide a stimulus for the specific adaptations that will result in improved athletic performance. The maintenance or improvement in performance standards is not, however, solely determined by appropriate conditioning. The ability of bodily systems (e.g., neuromuscular system, endocrine system) to recover and regenerate following composite stresses including strenuous physical activity, psychological stress of practice and competition, etc., can also influence physical performance. Of particular importance to force development is the manner in which muscles respond and remodel following exercise stressors. When a player is training, practicing and competing, the dynamic homeostatic balance created between anabolic (building) and catabolic (breakdown) processes within the muscle can ultimately influence muscular force characteristics and, therefore, affect the quality of a player's performance.

It can be a challenge to prescribe an optimal training program for an athlete, or team and quantify exactly the right combination of volume and intensity. Markers for monitoring an athlete's recovery do not appear to be well researched and validated in team, anaerobic sports. Generally, after an overload stimulus, a catabolic state results with decreased tolerance of effort; this state is characterized by reversible biochemical, hormonal and immunological changes (Urhausen & Kindermann, 2002). Following the catabolic state, an anabolic phase process incurs with a higher adaptive capacity and enhanced performance capacity. It is during this anabolic phase, termed supercompensation, when the training stimulus is most effective. The degree of supercompensation achieved depends on the size of the stimulus for adaptation and therefore, the degree of imbalance between anabolic and catabolic processes. An optimal training program capitalizes on the athlete's stress tolerance and his or her adaptive ability. If full recovery is not permitted between training sessions a valley of fatigue may result (Fry, Morton & Keast, 1991).

Overtraining Syndrome can be defined as an imbalance between the training stimulus and recovery. It is a general term used to describe the process of training excessively and the fatigue state and symptoms that may develop as a consequence (Calister et al., 1990). It is characterized by sub-par sport-specific physical performance, accelerated fatigability and subjective symptoms of stress. (Urhausen & Kindermann, 2002). Overtraining is the stimulus; a single consequence may be what is detrimental to an athlete's performance. An imbalance between the overall strain of training and the individual's tolerance of stress over time can lead to overtraining. However, it is important to note the short-term fatigue felt after overload training is not overtraining syndrome, when it reversed with unloading periods and adequate recovery.

In strength/power athletes overtraining has been attributed to alterations in both training volume and training intensity (Hoffman, 2000), whereas endurance athletes often attribute OTS to volume alone. It seems that changes to either variable without sufficient rest or recovery can cause overtraining in these types of athletes. The occurrence of fatigue and other stages of overtraining depend primarily on how the individual athlete responds to the specific training stimulus. This can be problematic in a team sport where the training program is developed for the team as a whole and not for the individual athlete (Hoffman, 2000).

Rating of Perceived Exertion: A Measure of Training Stress

The ability to monitor training is critical to the process of evaluating and quantifying a periodized training plan. Endurance athletes have often used distance as a means of documenting the training volume and heart rate as a measure of intensity. On the other hand, intermittent, high intensity sports are very difficult to quantify (Foster et al., 2001) Using volume alone will neglect the important variable of intensity, and intensity can vary within an interval training, weight training or plyometric training session.

Evaluating a training session using a type of rating of perceived exertion scale (RPE) has been shown to be a useful and practical tool in correlating the physical demands on the body over time with athletes that could be possibly overtraining (Anderson et al., 2003). This type of scale allows researchers to quantify the training load and evaluate the trends in training load as prescribed by the coach, the athlete's perception of the load and the adaptation pattern relative to the load. RPE's can be obtained using a modified Borg scale, rating from easy to very intense on a scale of one to ten. Foster et al (2001 pp.111) found that this scale was highly correlated to summated heart rate zones of basketball players; in essence the "same critical information is contained with both methods." Athletes should be instructed to fill out the RPE directly after the training session and to give a global rating of the session, versus after one isolated drill or exercise. Foster et al (2001) and Lagally (2000), found that the RPE technique is reliable and consistent with objective physiological indices of intensity of exercise training. The athlete can also record the duration of the training session (Anderson et al., 2003) and an exercise score, or the training load, can be calculated by multiplying the session duration in minutes by the RPE (Foster et al., 2001). Also, subjects can monitor their practices and competitions this way (Foster et al 2001). Finally, the daily and weekly training loads can be calculated and presented graphically, allowing the coach to have a visual summary of adaptation to the periodization plan.

Subjective Measures of Adaptation to the Training Stress

Overtraining or maladaptation to a training program is primarily related to sustained high load training, "Often coupled with other stressors in the individual's life." (Foster, 1998 p.1164). Physiological markers that have been documented include chronic fatigue; sleep disorders and chronic muscle soreness and damage. The use of performance measures such as strength, speed and agility as well as monitoring sleep, stress, and fatigue is a good method of monitoring training stresses (Hoffman, 2000). Hopkins found (1991) in his review that various symptoms of overtraining can identified anecdotally. These are the inability to meet previously attained training targets, negative mood states, disturbed sleep, chronic muscle soreness and elevated resting heart rate. Gleeson (2002) also indicates these commonly reported physiological and psychological changes associated with overtraining: underperformance, muscle weakness, chronic fatigue, sore muscles, increased perceived exertion during exercise, reduced motivation, sleep disturbance, altered mood states and recurrent infection. Sports injuries have additionally been found as a result from associations between training patterns, daily stresses, and overtraining (Anderson et al., 2003).

These markers may prove to be an efficient and inexpensive method for monitoring athletes for overtraining (Hoffmann, 2000). These markers together with performance testing, a diary of training that rates perceived feelings of fatigue and muscle soreness may provide advance warning of impending overtraining (Gleeson, 2002). A log book that allows the athlete to document sleep, fatigue, stress and muscle soreness as developed by Hooper et al (1995), focuses on self-assessment by the athlete. This was proven to be useful, as physiological parameters such as heart rate, blood pressure and blood lactate may not differentiate between stale and non-stale athletes; other studies have shown a lack of significant changes in various physiological measures with overtraining (Hooper, 1995). Even biochemical parameters such as neutrophil counts and epinephrine levels may not provide accurate, and practical long-term monitoring tool for overtraining (Hooper, 1995).

Muscle Damage and Adaptation

Mechanical factors, namely muscle tension, during eccentric contractions and active strain on lengthened fibers have been identified as leading causes of muscle damage (Sayers & Dannecker, 2004). During eccentric muscle actions muscle fibers lengthen as they produce force result in more soreness than concentric muscle actions (Sayers & Dannecker, 2004). Eccentric muscle actions rarely occur in isolated, unijoint movement. Instead, muscle function in sport occurs in a sequence of active muscle eccentric action followed by an active concentric muscle action. This is known as the stretch-shortening cycle (Byrne, Twist & Eston, 2004). Since eccentric contractions contribute to the SSC, it is not a surprising phenomenon that muscle damage occurs during prolonged or intense exercise such as distance running, plyometrics and resistance training (Byrne et al., 2004). These activities are also commonplace in basketball training programs.

The physiological explanation that lies behind this process is that fewer motor units are recruited to handle the same load and the force per cross-sectional area of muscle, and tension per unit of active muscle mass is greater, which results in more damage to the muscle (Armstrong, 1984). At the cellular level, Z-line streaming, which is explained by Sayers and Dannecker as "disorganization of the area that joins the repeating contractile elements of the myofibrils together" and myofibrillar disruption are direct manifestations that muscle damage has occurred (2004, pp.79). Furthermore, calcium homeostasis and excitation-contraction coupling are also impaired as a result. Examination of eccentrically damaged muscle shows damage to the sarcolemma, T-tubules, myofibrils and the cyoskeleton (Sayers & Dannecker, 2004). Lieber et al. (1996) found that structural changes to the fiber are present as soon as 5-15 minutes post exercise.

Frieden et al (1985), examined muscle soreness and muscle fiber morphology during 8 weeks of eccentric training with increasing work loads. They found pronounced soreness during the first two to three exercise sessions. However, despite increasing work over time, symptoms of soreness were lower following training.

The Impact of Muscle Damage on Performance

It is common and normal to experience pain and muscle stiffness that accompanies a new training program. This phenomenon is known as delayed onset of muscle soreness, or DOMS, and is associated with muscle fiber injury incurred after novel activities. DOMS is most prevalent at the beginning of the sporting season when athletes are returning to training following a period of reduced activity (Cheung & Maxwell, 2003). DOMS is used to represent the clinical symptoms and signs that occur after muscle damage. Exercised muscles are generally pain free for approximately 8 hours and then soreness following exercise has a time course it follows (Byrne et al., 2004). DOMS begins the first 24-48 hours after exercise and peaks at 24-72 hours (Clarkson, 2002). All discomfort usually subsides within 96 hours (Byrne et al., 2004). Along with the soreness, comes other related symptoms such as prolonged muscle weakness, a decreased range of motion and muscle protein leakage into the blood plasma. DOMS can effect of athletic performance due to reductions in the force-producing ability of the muscle and range of motion, altered proprioception and gait biomechanics (Sayers & Dannecker, 2004). These effects can raise questions about whether or not to work through the pain or rest and recover.

There is evidence, in the literature, that neuromuscular function can be impaired by the performance of unaccustomed eccentric exercise that induces muscle soreness. Kinematic analysis of gait mechanics following DOMS has revealed reductions in range of motion about the ankle, knee and hip joints (Cheung et al., 2003). These changes could be due to a reduced range of motion in the quadricep muscle group and a subsequent reduction of shock absorption capability of the lower body (Cheung et al., 2003). Reductions in strength and power have also been documented by numerous researchers (Cheung et al., 2003). The duration of strength reduction, most notable in eccentric contractions, was found be 8-10 days. Concentric strength recovered more rapidly, in only 4 days (Cheung et al., 2003) Many researchers have unfortunately failed collect repeated strength data on back to back days which has important implications for the athlete who may be at risk for injury as they suffer through a deficit in a muscle group (Cheung et al., 2003). Muscle injury may also lead to altered recruitment patterns or changes in the temporal sequencing of muscle activation (Cheung et al., 2003). Findings of altered neuromuscular control such as time to peak EMG and time to peak contraction velocity have been researched and were found to persist for up to 5 days (Cheung et al., 2003).

Soreness incurred through training causes a loss in functional strength, stiffness, and an increase in creatine phosphokinase, a marker of muscle damage, in the blood plasma (Hamill, 1991). Performance may also be negatively affected by reduced muscle tension and range of motion about the associated joints; DOMS however, appears to have little effect on the kinematics of the lower extremity during gait. Instead, there is a decrease in economy of movement, impairment of glycogen repletion and or changes in the biomechanics of movement, thus increasing the risk of injury to the athlete (Smith, 1995). Since eccentric contractions are vital for shock absorption or braking in the direction of gravity (Smith, 1995), altered gait patterns can have negative effects on shock absorption abilities of the lower extremities.

DOMS is certainly a "subclinical" injury (Cheung et al., 2003). However, during a pre-season phase, athletes are often required to practice and train during periods of intense muscle soreness. The following risk factors should be noted during this time (Cheung et al., 2003):

1. DOMS can reduce the cushioning effect during landings and running. To compensate, increased shock absorption will occur at other joints causing unaccustomed strain.
2. Changes in co-ordination may also lead to unaccustomed strain to be placed on muscles, ligaments and tendons during functional activity.
3. A decrease in force output in a muscle group or to fibers of a muscle may lead to compensatory recruitment from uninjured areas leading to altered agonist/antagonist ratios and increased stress on compensating muscle groups.
4. An inaccurate perception of impairment or a reduction in DOMS may also cause an individual to return to high intensity activity before the muscle has adequately recovered.

It is widely accepted that training results in degrees of microtrauma to muscle, connective tissue and/or bones and joints. Adaptation to training stress is dependant on the preparation and maintenance of strength and flexibility (Kibler & Chandler, 1998), the degree of the demands and abuse of the activity and the amount of recovery before the next training session. Training adaptation can be quantified with less soreness and reduced enzyme release in subsequent bouts of activity. The adaptation process is believed to begin even before complete healing has occurred and results from an improved cytoskeletal structure and a neural adaptation (Nosaka & Clarkson, 1996).

It has been suggested that 3 training sessions per muscle group per week is a minimum frequency for gaining muscle size and strength (Nosaka & Newton, 2002). Therefore, if this training frequency is followed, some training sessions may be performed when the muscles are still experiencing delayed onset of muscle soreness (DOMS) from the previous session. Generally speaking, if exercise-induced muscle damage occurs, it can be harmful for the tissue to receive another damaging stressor again *early* in the recovery process (Nosaka & Newton, 2002). However, if the initial damage is induced via eccentric based activity like plyometric training this may not be the case. Previous studies have shown that performing repeated bouts of eccentric exercise 3 and 6 days (72-144 hours) after the initial bout did not result in further damage or retard the recovery process (Nosaka & Newton, 2002). However, motor unit recruitment patterns may be altered and in this vulnerable state, training may worsen present damage (Nosaka, 1995). Reductions in jumping performance, after exercise-induced muscle damage, lasted up to 4 days in a study by Byrne and Eston (2004). Also, an elevated physiological response to endurance exercise has been reported after muscle damaging exercise where breathing frequency, respiratory exchange ratio, heart rate and RPE were all significantly higher two days after eccentric exercise when compared with concentric exercise (Byrne et al, 2004). The practical question of whether to rest or perform recovery exercise after muscle damage remains unresolved (Byrne et al., 2004).

Currently no studies have examined muscle damage and soreness induced in a practical situation where more than 3 training sessions are adhered to per week, with some separated by less than 24 hours of recovery. Also, no studies have used highly trained subjects when measuring repeated bouts of eccentric exercise and the effects on DOMS.

Measuring Muscle Damage

Delayed onset of muscle soreness (DOMS) is the most commonly used indirect marker of muscle damage in human studies (Byrne et al., 2004). DOMS is usually associated with unfamiliar, high-force muscular work and is precipitated by eccentric actions (Cheung, 2003). As mentioned previously, training involving excessive eccentric loading will magnify DOMS and increase the level of direct structural damage to the muscle. Logically, the amount of muscle damage does often dictate the level of soreness (Clarkson, 2002). However, it is the process of chronic overloading of the musculature and maladaptation that can lead the athlete into a state of overtraining, which can escalate into chronic fatigue and decreased performance.

Pain serves a critical purpose. It acts as a reminder to the athlete that impairment to the muscle still exists. One of the methods used to quantify eccentric contraction-induced muscle injury, is the use of a visual analogue scale to record a level of soreness. The use of this type of scale is the most common marker of muscle injury in human studies (Warren et al., 1999). 63% of all human studies, analyzed by Warren et. Al. (1999), used a visual analogue scale or numerical scale for subjective evaluation of soreness. The sensation of soreness comprises muscle tenderness, pain on palpation and mechanical stiffness that results in pain when the muscle is stretched or activated (Byrne et al., 2004). However, soreness is not always correlated with impairments in muscle function (Warren et al., 1999). Soreness often occurs after the onset of contractile deficits and changes in the range of motion (Warren et al., 1999). Range of motion and torque values are affected much sooner in the recovery process, before DOMS sets in. Therefore DOMS, should not be used as an indicator of *functional* impairment because function is impaired before soreness arises and damage worsens when soreness has dissipated (Byrne et al., 2004).

The athlete and the strength and conditioning coach should be aware of the potential implications of exercise-induced muscle damage on sport performance and the time course for recovery between training sessions. Periodization plans must account for the days following eccentrically biased training, which results in mechanical muscle damage. Prevention has been identified as the most appropriate approach to overtraining, thus emphasizing the role of thoughtful planning of training and recovery is critical (Byrne et al., 2004). Byrne et al state that "of particular concern is the approach to optimizing recovery following muscle damaging exercise, allowing an immediate return to training and further competition, as is commonly associated with intermittent, high-intensity activities" (pp. 68).

If the physical demands of practice, conditioning, and competition are too great, it might be hypothesized that catabolic activities will predominate. If, however, the body is able to successfully cope with the demands, anabolic metabolism can help to maintain or improve performance over the course of an 8-week pre-season period. Nevertheless many factors impact this delicate metabolic balance, including conditioning activities, practice schedules, academic demands, psychological stressors, sleep quality, and competition, each contributing to the overall physiological status of a player. This supports the rationale behind documenting training volume, intensity, and performance and the individual, versus the team, adaptive process on a daily basis.

Appendix C: Treatment group training program

Phase: Pre-Season Camp								
DAY 1: Monday	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Exercise	**13-Sep**	**20-Sep**	**27-Sep**	**04-Oct**	**11-Oct**	**18-Oct**	**25-Oct**	**01-Nov**
Bent Knee Deadlift	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps
Power Shrugs	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps
High Pulls	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps
Bent Over Row	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps	8 reps
		increase wt			increase wt		same weight	
1. Hang Cleans - explosive	4 x 6	4 x 4	2 x 6	4 x 4	4 x 4	3 x 6	3 x 4	3 x 4
Rest:	4 min	4 min	3 min	4 min	4 min	4 min	4 min	4 min
2. Bent over barbell row 2:2 ss #3	4 x 8	4 x 8	4 x 10	4 x 10	4 x 8	3 x 8	3 x 10	3 x 10
3. DB Press with Hip Drive 1:2	4 x 8	4 x 8	4 x 10	4 x 10	4 x 8	3 x 8	3 x 10	3 x 10
Rest:	2.5 min	2.5 min	2.5 min	2.5 min	2.5 min	2.5 min	2.5 min	2.5 min
4. SA SL Lateral Raise 1:1:2	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si
Rest:	2 min	2 min	2 min	2 min	2 min	2 min	2 min	2 min
5. BOSU Shoulder Press ss #6	3 x 8	3 x 8	3 x 10	3 x 10	3 x 8	3 x 8	2 x 10	2 x 10
6. SB Inverted Chin-ups	3 x max	3 x max	3 x max	3 x max	3 x max	3 x max	2 x max	2 x max
Rest:	2 min	2 min	2 min	2 min	2 min	2 min	2 min	2 min
7. Forward Alt Power Lunges 1:1	3 x 8/side	3 x 8/side	omit	3 x 8/side	3 x 8/side	3 x 8/side	2 x 8/side	2 x 8/side
Rest:	90 sec	90 sec	omit	90 sec	90 sec	90 sec	90 sec	90 sec
CORE								
Elbow Digs	3 x 60 sec	3 x 60 sec	3 x 60 sec	3 x 60 sec	3 x 60 sec	2 x 60 sec	2 x 60 sec	2 x 60 sec
Knee tucks on one leg	2 x 12/leg	2 x 12/leg	2 x 12/leg	2 x 12/leg	2 x 12/leg	2 x 12/leg	2 x 12/leg	2 x 12/leg
Roll-outs	3 x 12	3 x 12	3 x 12	3 x 12	3 x 12	2 x 12	2 x 12	2 x 12

DAY 2: Thursday COMPLEXES	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Exercise	**16-Sep**	**23-Sep**	**30-Sep**	**07-Oct**	**14-Oct**	**21-Oct**	**27-Oct**	**03-Nov**
(Warm-up) 1 x through						**taper**		
Balance Board Squats	10	10	10	10	10	10	10	10
Balance Board Lunges	10/side	10/side	10/side	10/side	10/side	10/side	10/side	10/side
Balance Board push-ups (w/n/SL)	5/5/3/3	5/5/3/3	5/5/3/3	5/5/3/3	5/5/3/3	5/5/3/3	5/5/3/3	5/5/3/3
Oly Bar Squats to toes	10	10	10	10	10	10	10	10
1. Back Squats onto toes ss	3 x 8	3 x 8	3 x 10	3 x 10	3 x 8	2 x 8	2 x 10	2 x 10
Dumbbell Jump squats at 30% max	10 reps	12	12	15	10	6	6	6
Rest:	3 min	3 min	3 min	3 min	3min	3min	3min	3 min
2. Standing Oly bar Press ss 1:3	3 x 8	3 x 8	3 x 10	3 x 10	3 x 8	2 x 8	2 x 10	2 x 10
Oly bar throws catch same si 1:1	10 reps	12	12	15	10	6	6	6
Rest:	3 min	3 min	3 min	3 min	3min	3min	3min	3 min
3. Standing Squat to Row 1:3	3 x 8	3 x 8	3 x 10	3 x 10	3 x 8	2 x 8	2 x 10	2 x 10
ss Lat Row SL Jump and stabilize 1:1:2	10 reps	12	12	15	10	6	6	6
Rest:	3 min	3 min	3 min	3 min	3min	3min	3min	3 min
4. SA/SL DB Cleans - explosive	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si
Rest:	2 min	2 min	2 min	2 min	2 min	2 min	2 min	2 min
5. Alternating Oly Bar side squats 1:2	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 6/si	omit	omit
ss Lateral power-overs (12 " bench)	10 total	10 total	10 total	10 total	10 total	10 total	10 total	10 total
Rest:	2 min	2 min	2 min	2 min	2 min	2 min	2 min	2 min
6. Power Fwd lunge ss 1:1	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 8/si	2 x 6/si	omit	omit
Split Jumps max height 1:1	10 total	10 total	10 total	10 total	10 total	10 total	10 total	10 total
Rest:	2 min	2 min	2 min	2 min	2 min	2 min	2 min	2 min
CORE								
SL Squat on bench with ball taps	1 x 8/side	1 x 8/side	1 x 8/side	1 x 8/side	1 x 8/side	1 x 8/side	1 x 8/side	1 x 8/side
Dual Instability push-ups	2 x max	2 x max	2 x max	2 x max	2 x max	2 x max	2 x max	2 x max
SB Leg Curls	2 x 12	2 x 12	2 x 12	2 x 12	2 x 12	2 x 12	2 x 12	2 x 12
BIKE 20 min recovery easy load								

Pre-Season Lifting Program								
Phase: Pre-Season Camp								
DAY 3: Saturday	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Exercise	**11-Sep**	**18-Sep**	**25-Sep**	**02-Oct**	**09-Oct**	**16-Oct**	**23-Oct**	**30-Oct**
(Warm-up)				game	game		game	game
Med ball Chest Passes with one step	20 passes	20 passes	20 passes	day	day	20 passes	day	day
Med ball One arm Push Pass	20/side	20/side	20/side	off	off	20/side	off	off
1. Jammer Press	3 x 8	3 x 8	3 x 8			3 x 8		
Rest:	3 min	3 min	3 min			3 min		
2. One arm DB Snatch	3 x 8	3 x 8	3 x 8			3 x 8		
Rest:	3 min	3 min	3 min			3 min		
3. One arm one Leg Row	2 x 10/si	2 x 12/si	2 x 15/si			2 x 15/si		
Rest:	2 min	2 min	2 min			2 min		
4. Balance Board Push-ups on 1 leg	2 x max	2 x max	2 x max			2 x max		
CORE								
Hip Twisters	2 x 40 sec	2 x 40 sec	2 x 40 sec			2 x 40 sec		
SB Tricep Press	2 x max	2 x max	2 x max			2 x max		

Plyometrics and SAQ Program (Tuesdays)

Week	Drill	Prescription
1	Single leg Squats	1 x 10
	Single Leg Jumps and land	1 x 10
	Single Leg Calf Raise	1 x 10
	Slalom Hops over the line and stick landing	1 x 10
	Single leg Line Jumps	1 x 10
	Ankle Hops	2 x 20
	Squat jumps	1 x 10
	One step into vertical jump	1 x 10
	Side step into vert jump	2 x 10
	Back step into vert jump	1 x 10
	Quick feet over hurdles (lateral stepping)	3 x 3 per direction
	Hurdle Figure 8's	3 x 15 seconds
2	Single leg Squats	1 x 10
	Single Leg Jumps and land	1 x 10
	Single Leg Calf Raise	1 x 10
	Slalom Hops over the line and stick landing	1 x 10
	Single leg Line Jumps	1 x 10
	Ankle Hops	2 x 20
	Squat jumps	1 x 10
	One step into vertical jump	1 x 10
	Side step into vert jump	2 x 10
	Back step into vert jump	1 x 10
	Power Skips	2 x 20
	Bounding	2 x 20
	Quick feet over hurdles (lateral stepping)	3 x 3 per direction
	Hurdle Figure 8's	3 x 15 seconds

Week	Drill	Prescription
3	Single leg Squats	1 x 10
	Single Leg Jumps and land	1 x 10
	Single Leg Calf Raise	1 x 10
	Slalom Hops over the line and stick landing	1 x 10
	Single leg Line Jumps	1 x 10
	Ankle Hops	2 x 20
	Squat Jumps on the Spot with one step from four directions	1 x 10 of each (40)
	Lateral Hurdle Hops	2 x 10
	Forward hurdle hops	6 x 5
	2 hops down and 1 hop back	2 per direction with 13 contacts each
	Power Skips	2 x 20
	Bounding	2 x 20
	Quick feet over hurdles (lateral stepping)	3 x 3 per direction
	Hurdle Figure 8's	3 x 15 seconds
4	Single leg Squats	1 x 10
	Single Leg Jumps and land	1 x 10
	Single Leg Calf Raise	1 x 10
	Slalom Hops over the line and stick landing	1 x 10
	Single leg Line Jumps	1 x 5/leg
	Power Skips	3 x 20
	Bounding	2 x 20
	Ankle Hops	1 x 20
	Single Leg Ankle Hops	2 x 10/leg
	Lateral Hurdle hops	2 x 10
	Single Leg Lateral Hurdle Hops	2 x 6/leg
	2 down, one back over hurdles	1 x 13 per direction
	Quick feet over hurdles (lateral stepping)	3 x 3 per direction
	Figure 8's	3 x 15 seconds

Week	Drill	Prescription
5 *unloading	First 5 exercises same as week 4	
week	Close out to backpedal shuffle	3 x 15 sec
	T-test practice and re-test ***	3 reps with 10 x rest
	Lateral steps over hurdles narrow load outside foot	2 x 20 sec
	Same but load is wide on this set	4 x 20 sec
	Over 5 hurdles and weave hurdles relay race	2 x 4 reps each
Week 6	Same 5 exercises as week 4 and 5 to start	
	Squat jumps	1 x 10
	One step into vertical jump	1 x 10
	Side step into vert jump	2 x 10
	Back step into vert jump	1 x 10
	Depth Jump into vert jump	1 x 10
	Depth jump into open step with coaches cue	1 x 10
	Backwards depth jump into open step/pivot with cue	1 x 10
	Lateral Bench Hops	2 x 10 for speed
	Two down one back over hurdles	1 x 13 contacts on two feet
	Same as above but on one foot	1 x 13/foot
	Figure 8's	4 x 20 sec
	Lateral in and out with load	4 x 20 sec
Week 7	Fun hip hop dance session	45 minutes

Friday Anaerobic Conditioning Drills

Prescription: 3 drills, 6 sets per drill of 30 seconds work with 90 seconds recovery : Weeks 1,2,3
3 drills, 6 sets per drill of 45 seconds work with 45 seconds recovery : Weeks 4 and 5

Drill: Full Court Sprints
Distance: Basketball floor baseline to baseline linear sprints

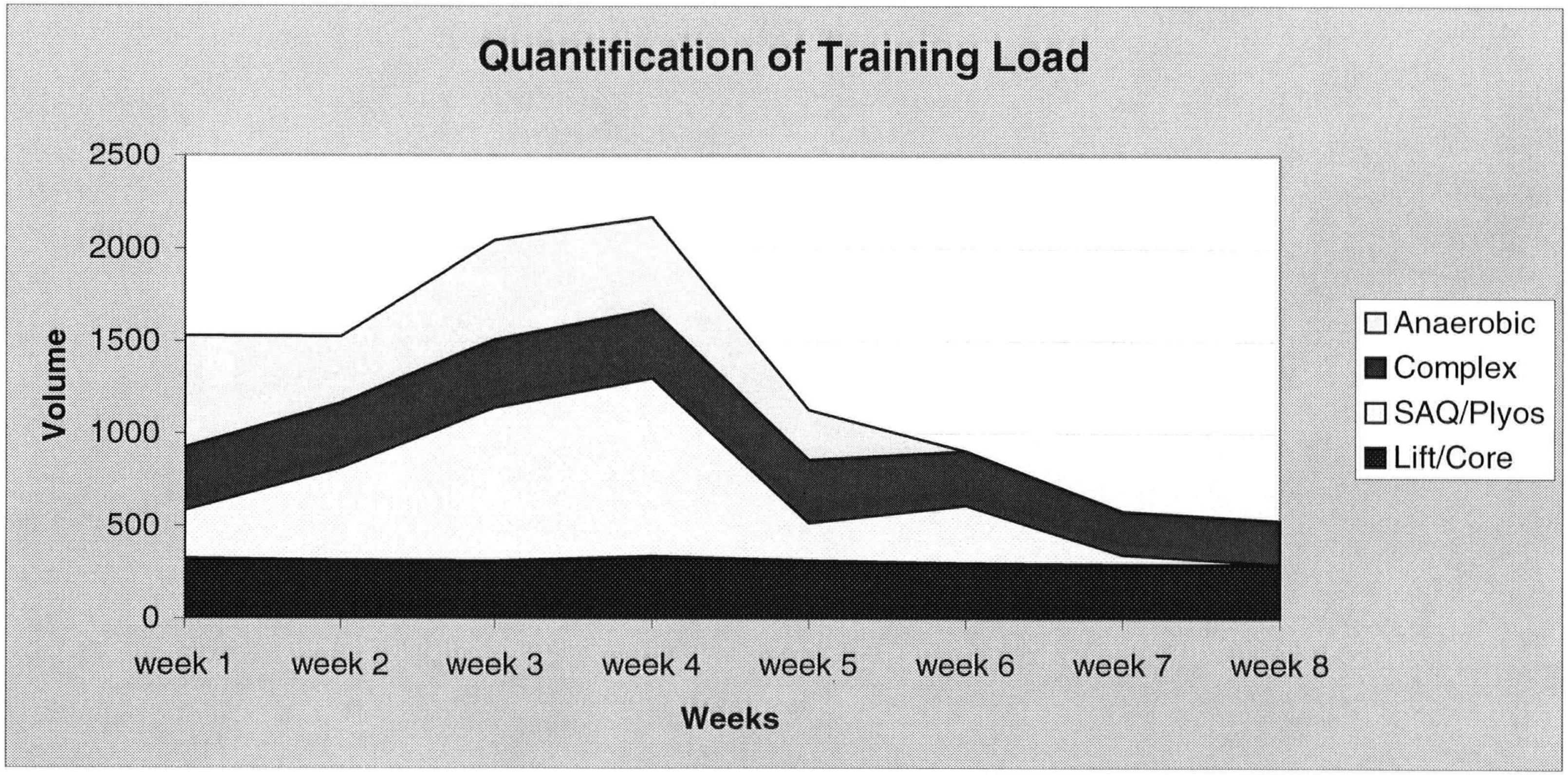
Drill: Complete the Square
Distance: Use the key
defensive shuffle bottom of key
sprint to top of key
defensive shuffle across top of key
backpedal to start

Drill: Shuffle N' Jump
Distance: N/A
In a low, athletic stance, shuffle to the right 3 times, jump as high as you can
Land on both feet and immediately shuffle to the left
Repeat for the time prescribed

Drill: Multi-directional ¾ Court Suicides
forward run to top of key
backward run to baseline
forwards run to center
carioca step to baseline
side shuffle to far free throw line
forwards run back to baseline
Jog slow to opp baseline and then slow back to start

Figure 19. Quantification of training load

* all training methods for the treatment group: Anaerobic conditioning, complex training, plyometrics and agility and resistance training Note peak of load at week 4 and taper towards week 8



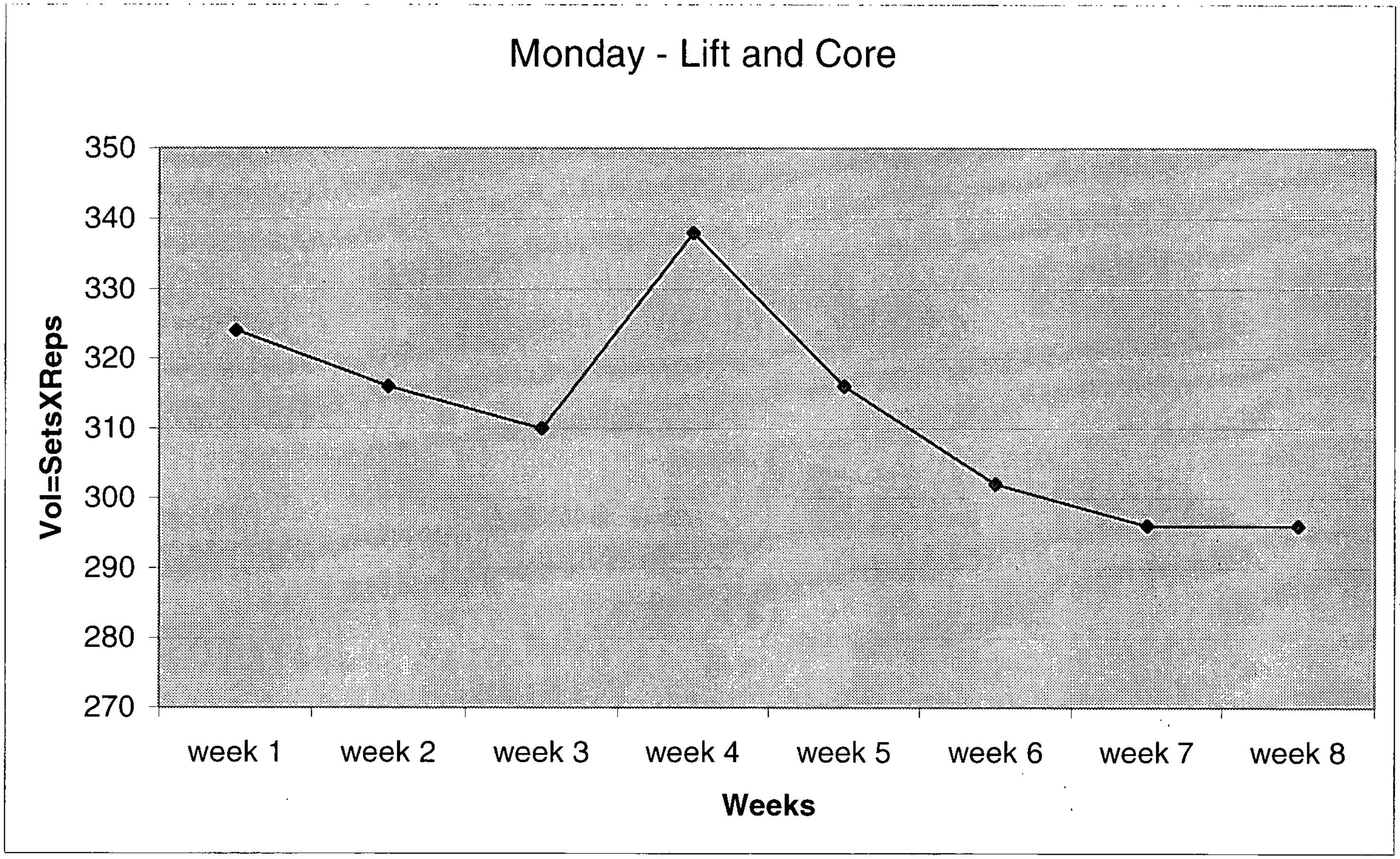


Figure 20. Training Load for monday lifting session, sets x repetitions

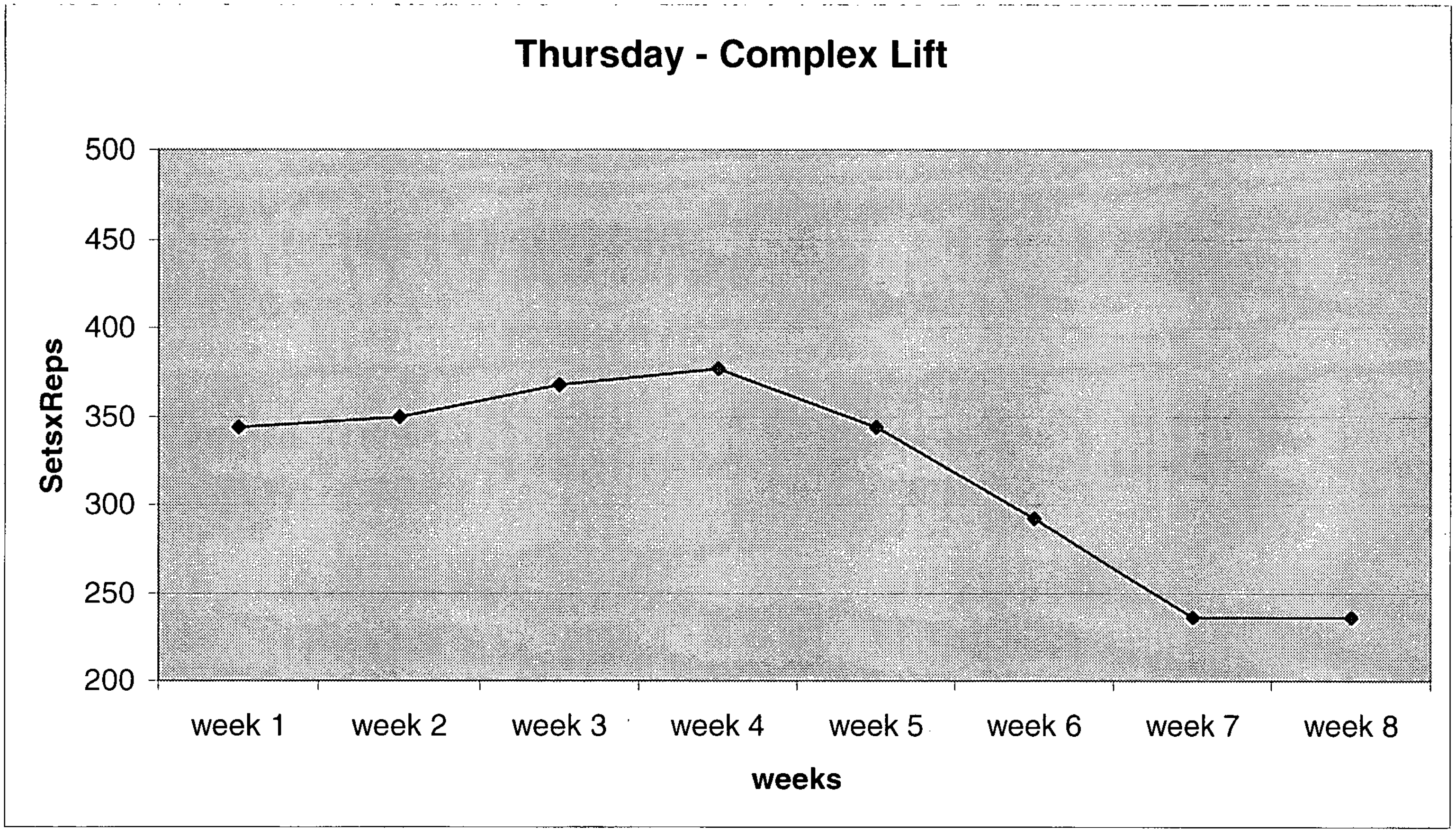


Figure 21. Weekly variation in training load for Thursday, sets x repetitions

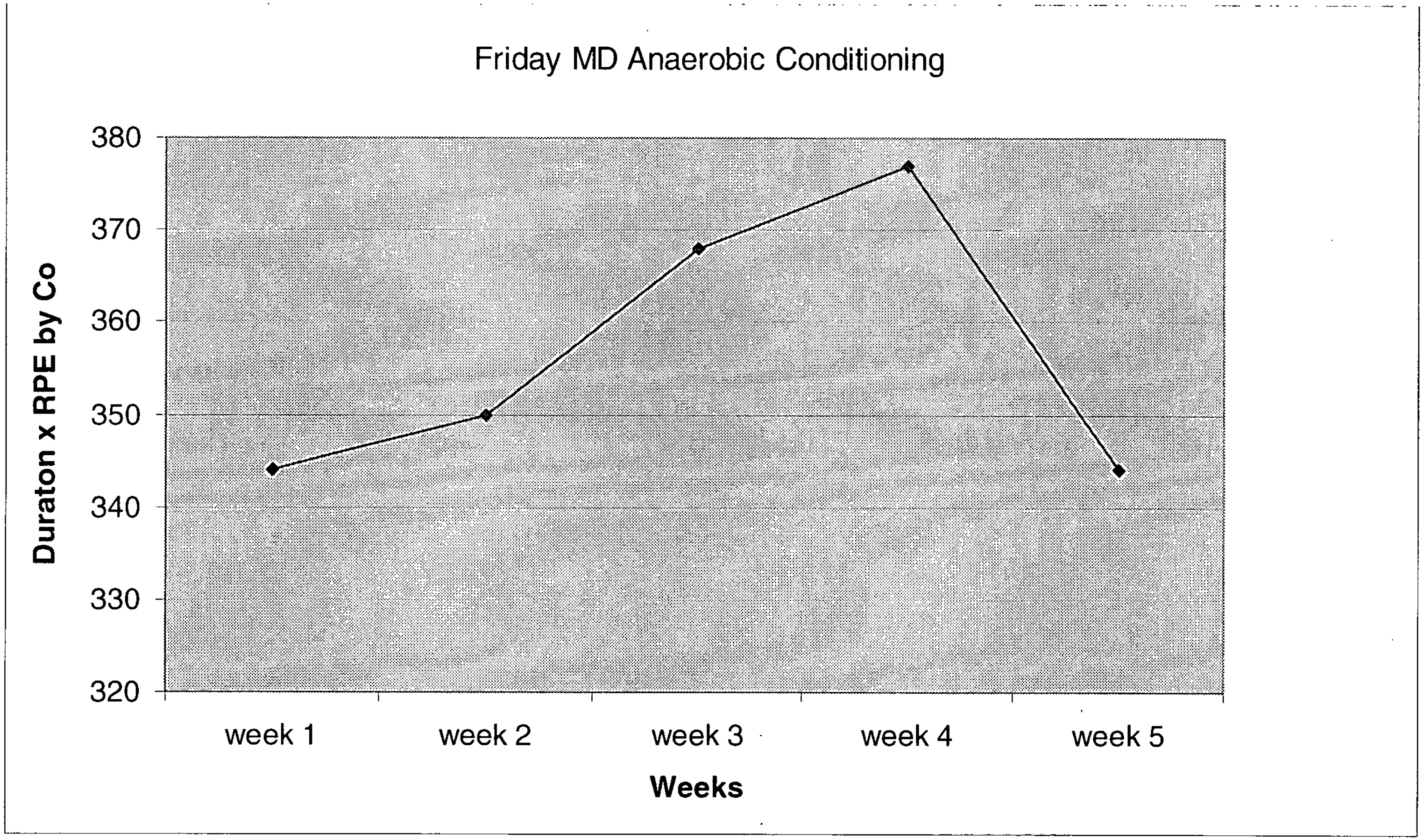


Figure 22. Weekly variation in training load for Friday's session

Appendix D. Treatment Group Training Log Example

Figure 23. How to complete the athlete daily training and adaptation log

How to complete the training log:

1. In the time column, insert the time the session began

2. In the duration column, insert each session's duration in minutes (including warm-up and cooldown)

3. In the activity column, insert the type(s) of training according to the following legend:
C = Conditioning (running, stairs, multi-directional intervals)
L = Lift (includes weight training and core training)
R = Rest (no training)
A = Agility (includes ladders, cone drills, and shadowing drills)
Plyos = Plyometrics (includes jumping drills, medicine ball drills)
P = Practice (includes team and individual practice)
G= Game (includes scrimmages, intersquad games, tournaments and exhibition games)

4. In the Rating of Perceived Intensity (RPE) column, please rate the session by number to indicate how hard the session was. Make sure to do this for your training session AND your practice or game session.
See RPE table on right for the RPE rating scale and corresponding level of intensity.

5. DOMS (Muscle soreness) in lower body only. Please draw a vertical line over the line on the sheet to indicate how sore
your *leg* muscles feel
(0 = pain free, 10 = very sore)

6. Sleep quality - please rate how well you slept THE NIGHT BEFORE on a scale of 1-10
(1 = excellent, 10 = no sleep)

4. RPE TABLE

Rating Scale	
0	rest
1	very,very light
2	very ight
3	fairly light
4	moderate
5	somewhat hard
6	hard
7	very hard
8	very, very, hard
9	extremely hard
10	maximal

7. Stress - please rate how stressed you feel during that day on a scale of 1-10 (1 = no stress, 10 = extreme stress)
8. Fatigue - please rate how tired you feel throughout the day on a scale of 1-10 (1 = rested, 10 = exhausted)
9. Note: Injuries/Bruising/Swelling/Joint Pain, Use of Ibuprophen - Please indicate in writing any injuries that occurred or have Worsened. Please indicate what body part has been injured and what side. Please list how much ibuprophen taken on this day.

Figure 24. Daily Training and Adaptation Log

UBC Thunderbirds Women's Basketball Training Log Week # _____ Subject # _____

Date:	***Training***	Time	Duration	Activity	Rating of Perceived Intensity
Monday					rest 0 1 2 3 4 5 6 7 8 9 10 maximal
	Practice or	Time	Duration	Activity	Rating of Perceived Intensity
	Game (circle)				rest 0 1 2 3 4 5 6 7 8 9 10 maximal
	General	Sleep	Stress	Fatigue	no pain ├──────┤ very sore DOMS Rating Lower Body
Scale 1-10					
	Note: Injuries/Bruising/Swelling/ Joint Pain, Use of Ibuprophen:				