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Effect of High-Speed Treadmill Training with a Body Weight Support System in a Sport Acceleration Program

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High-Speed Treadmill Training with a Body Weight Support System

in a Sport Acceleration Program

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ABSTRACT

High-Speed Treadmill Training with a Body Weight Support System
In a Sports Acceleration Program

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Introduction: Maximum running acceleration essential components in many sports. The identification of specific training protocols to maximize sprint speed would be useful knowledge for soccer coaches and players.

Purpose: The purpose of this study was to determine the effect of a high-speed treadmill with the use of a body-weight support system in a 6-week sport acceleration program on: 40-yard sprint time, maximal isometric knee flexor and extensor strength.

Methods: 32 female soccer players (age 16 ± 1.19 yrs) participated in two treatment groups and one control group. Both treatment groups participated in a 12-session sport acceleration program. The first treatment group utilized a body-weight support system while on a high-speed treadmill; the second group used a standard treadmill with no body weight support system. The control group, NT, did not participate in a sports acceleration program and did not alter their exercise routines outside of the study.

Results: For each variable an Analysis of Covariance (ANCOVA) was performed. 40-yard sprint times for treatment groups were shown to improve significantly as compared to the control group *(p = 0.0007* for high-speed treadmill with body-weight support system, *p= <0.0001* for standard treadmill without body-weight support system). Isometric flexor and extensor strengths did not show significant differences between treatment groups and control group. P-values for the high-speed with body-weight support system were *(p = 0.53)* for flexors and *(p = 0.51)* for extensors as compared to the control group. P-values for the standard treadmill with no body-weight support system were *(p = 0.19)* for extensors and (*p = 0.0263)* for flexors. It is noted that the extensor muscles were nearly significant for the standard treadmill with no body-weight support system.

Discussion: These results can help high school coaches and athletes determine the optimal treadmill training regime. The current study shows that a high-speed treadmill with body-weight support system is just as beneficial as standard treadmill training

Keywords: body weight support system, high-speed treadmill, sport acceleration program, speed, agility, sprint, isometric knee flexor strength, isometric knee extensor strength, injury, soccer.

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Introduction

Maximum running speed and acceleration are essential components in many field sports (Bangsbo, Nørregaard, & Thorsø, 1991). Training for these sports has increased the emphasis on the improvement of speed and sprinting (Dintiman & Ward, 2003). The United States began researching ways to improve acceleration in the 1960's but only looked at genetics at that time (Dintiman & Ward, 2003). Currently, research focuses on sprint-assisted training, speed-strength training, plyometric training, and stopping, starting, cutting, and accelerating (Ross, 2009, Thomas, 2009, Harrison, 2009, Dintiman & Ward 2003, Sedano, 2010).

As competition levels continue to rise, performance experts are developing higher levels of sport specific fitness programs. Sports camps and training programs for young athletes are held around the country (L. E. Brown & Ferrigno, 2005). Athletes train using specific drills and techniques to enhance their performance. For sprinting, speed in the initial steps of a sprint is viewed as being significantly important (Penfold & Jenkins, 1996) and is often a focal point of these programs. Though each program varies in method, the objective driving the programs is the same – improve an element of athleticism.

Research focusing on sport acceleration programs (SAP) suggests that female soccer players utilize a 4-12 week program outside of typical soccer training (Roozen, 1995, Thomas, 2009, Yap, 2000, Sedano, 2010). Speed, strength, agility, and power are essential aspects of SAP where a variety of methods are used to improve performance. Sprint (often called acceleration in these programs) training, plyometrics, strength training, and agility drills are the foundational basis of these programs. These multi-week (varying from 4-12 weeks) workouts are thought to help athlete's peak just prior to a season or tryout (Shepherd, 2002, Schweigert & Frappier, 2002, L. E. Brown, Ferrigno, & Santana, 2000). High-speed treadmill running is one such method issued to increase speed. Generally, athletes are taught and trained to run at high speeds on an incline, occasionally with resistance, in an attempt to increase leg strength and speed.

Many SAP programs use the high-speed treadmill in conjunction with varying resistance training protocols; however, very few programs use a body-weight support (BWS) system while running on the high-speed treadmill. This BWS system is a harnessing system that helps unweight athletes so they can train at higher velocities that would be otherwise unattainable in a safe environment. The harnessing system consists of an unweighting station, cable bar assembly, control panel, and a harness vest, which lifts approximately 10% of body weight using a compressor. Reported ranges of partial weight supporting ranged from 1-40% of a person's weight (Lewek, 2011, Gravano, 2011, Hesse, 2008, Ada, 2010, Moore, 2010).

Few studies could be found which have investigated the use of BWS. Lewek found that 40% BWS can alter step length, ground reaction forces, and ankle kinetics (Lewek, 2011). At a walking pace (1.2 m/s), BWS with a harness was found to decrease anteroposterior and vertical acceleration while mediolateral trunk movement increased (Aaslund, 2008). For stroke patients, aerobic treadmill training has been shown to improve speed and endurance and allow for independent walking without worsening gait quality (Hesse, 2008, Ada, 2010). Partial body-weight support can allow aggressive running training soon after a lumbar disk injury when normal impact forces cannot be tolerated (Moore 2010). No primary research investigating the use of high-speed treadmills and BWS was found.

Previous studies on SAP did not define, but state success in improving athleticism (Shepherd, 2002, Schweigert & Frappier, 2002, L. E. Brown, Ferrigno, & Santana, 2000). Other studies show significant or nearly significant increases in strength and speed with sprint training, plyometrics, resistance training, and combined sprint and resistance training (Ross, 2009, Kristensen, 2006, Mero, 1992, Mero, 1986, Callister, 1988, Spinks, 2007, Zafeiridix, 2005, Bloomfield, 2007, Jovanovic, 2011).

Research and discussion of SAP include topics of speed, quickness, agility, plyometrics, and strength training (Yap, 2000). Most recently a study determined that SAP appear to be an effective way of improving some segments of power performance in young soccer players during the in-season period (Jovanovic, 2011). While many studies have looked at SAP, there is no consistent trend found in the results of these studies. Research on SAP has generally shown improvements in one aspect of testing varying from jumping, overall speed, agility, or beginning acceleration (Ross, 2009, Kristensen 2006, Mero, 1992, Mero, 1986, Callister, 1988, Spinks, 2007, Zafeiridix, 2005, Bloomfield, 2007, Jovanovic, 2011).

SAP research focuses on plyometric jumping, though results vary with each study (Thomas, 2009, Sedano, 2010, de Villarreal, 2009, Wilson, G 1997). Sedano found that a plyometric program will increase explosive strength, acceleration, and kicking speed (Sedano, 2010), while Thomas found there was no change in sprint performance but was change in vertical jump height and agility time (Thomas, 2009).

The primary purpose of this study was to determine the effect of utilizing a body un-weighting support system during high-speed treadmill training on an athlete’s timed 40-yard sprint as well as the maximal isometric knee flexor and extensor strength during a sport acceleration program.

Methods

Participants

Thirty-two subjects completed this study (age 16 ± 1.19 years, height 1.64 ± .42 m, and weight 58.1 ± .95 kg. Thirty-nine females playing for a Utah County accelerated soccer team were randomly placed in 3 groups (2 experimental and 1 control group). The 2 experimental groups consisted of 16 and 14 participants respectively. Nine participants were randomly placed in the control group.

The 3 groups of participants were 1) High-speed treadmill with harness (HS), 2) Standard treadmill without harness (ST), and 3) Non-training control group (NT). Participants in the HS and ST groups were randomized into their respective groups by creating a sample pool of all participants and randomly selecting them for one of the two groups. Randomization was done by drawing pieces of paper with the group listed on it. After these two groups completed the 12-sessions of training, the control group participants were randomly recruited from accelerated soccer teams.

Age, height, mass, and previous injuries were recorded previous to data collection. Inclusion criteria required participants to be free of all extremity and spinal injuries for the past 6 months, no use of performance-enhancing substances, and a 6-7 week commitment time frame. Each subject and/or legal guardian signed a consent form approved by the university Institutional Review Board prior to any testing.

Four of the 16 participants in the high-speed training with the body-weight support (BWS) harness (HT) dropped out. One participant sustained a concussion, 2 sustained ankle sprains, and the fourth reason is unknown. Two participants dropped out of the standard treadmill with no BWS harness group (ST) due to an MCL tear and inability to complete the study in the 6-7 week time frame. One participant dropped out of the control group due to an ACL tear. All participants who dropped out because of injury sustained the injuries during soccer practice or games outside of the study.

One overuse injury, shin splints, was reported during the study in the HS group. Overuse injuries were reported in participants in the ST group while participating in the study as follows: 4 moderate to severe shin splints, 1 knee pain, and 3 arch pain. No injuries were reported in the NT group. Final participant numbers in the HS, ST, and NT group were 12, 12, & 8 respectively. One overuse injury was reported in the HS group, shin splints. Overuse injuries were prevalent in participants in the ST group; 4 reported moderate to sever shin splints, 1 of ongoing knee pain, and 3 with arch pain. No injuries were reported in the NT group.

Experimental Design

A 2x3x3 factorial design was used in the study. The first factor was time (two levels – pretest and posttest separated by 6 weeks), the second factor being the treadmill program (3 levels – a sport acceleration program using high speed treadmill training with a harness, a sport acceleration program using standard treadmill training with no harness, and no training), and the third factor were the dependent variables: 1) 40-yard sprint, 2) strength (MVIC) at 45 degrees knee flexion during a maximal isometric extension contraction, and 3) strength (MVIC) at 90 degrees knee flexion during a maximal isometric flexion contraction.

Protocol

Qualified participants were asked to perform a battery of tests, as typically performed as part of Central Utah Clinic's pretesting for their SAP. Participants were also tested on their 40-yard sprint time, flexor isometric strengths in supine position with knees at a 45-degree angle, and knee extensor isometric strength in a seated position with knee at a 90-degree angle during the pre and posttest. The 40-yard sprint was performed first during pre and post testing while the flexor and extensor strengths were tested at the end of the pre and post testing. Sprints were timed using a Sportline 220 Sport timer. Flexor and extensor strengths were measured using a Hoggan ergoFET Dual Function Push/Pull testing device (Hoggan Health, Industries, West Jordan). For flexor measurements the ergoFET was attached to a wall. Participants were prone on a table with knee at 90 degrees. ErgoFET was then attached to their ankle and peak force measurements were observed with hamstring contraction. For extensor measurements, the participant sat in a chair with ergoFET attached to a bar under the chair and then to her ankle. Peak force measurements were observed for at 45 degrees of knee flexion.

Participants in the HS and ST groups completed the 12-session sport acceleration program as outlined by Central Utah Clinic (Appendix A-1), which included the respective treadmill training protocol. The SAP program at Central Utah Clinic used in this study included: 9 ladder drills, 36 five-second plyometric/agility dot drills (single and double leg), iso-lexr back strengthening exercises, bosu-ball planking (side planks, push-ups, and starfish sit-ups), lateral resistor band drills - lateral & front stabs, medicine ball sit ups & chest press, single and double leg plyometrics training on the Shuttle MVP Pro, and a 12 minute workout on the treadmill (including the 2 minute warm up).

Treadmill training consisted of a 2 minute warm up at 0% incline at 6-8 mph, with no harnessing for participants in the HS and ST groups, after which the 10-minute treadmill training protocol began. A series of 3 treadmill training routines were repeated throughout the 6-week training program (Table 1). Central Utah Clinic's standard unweighting is 10-20% of an athlete's weight, and was used for the current study.

For both treatment groups, the first series of treadmill training was 10-second sprints with 40-60 second rests at a maximum incline of 10% for a total of 10 minutes. The second series of treadmill training was 5-second sprints with 20-40 second rests at a maximum incline of 10% for a total of 10 minutes. Treadmill velocity was increased as tolerated both within the session and throughout the 12 session program. Speeds varied from 8-22 mph for any given athlete. The final series of treadmill training was 360° lateral sprints at 0% incline with rests as needed. The participant turned 90 degrees according to verbal cues until facing forward again. The third series of treamill traning was finished with 5 second sprints at 0% incline for 2-3 minutes.

During the treadmill training portion, HS participants used a harnessing system which lifted 10-20% of their body weight (Figure 1). The ST group completed the same protocol with no harnessing system. Participants in the treatment groups were asked to sprint at their personal maximal speeds; maximal speeds for the HS group ranged from 18-22 mph, while the ST group's maximal speeds were15-18mph. Beginning sprint speeds and recovery periods between sprints were also individualized for each participant within reported ranges. Participants in the HS group were trained overall at higher speeds due to the safety provided by the harnessing system. After the 12 session training period, all participants repeated the pretesting protocol.

The NT group completed the prettesting portion of the study and were instructed and agreed to maintain their exercise levels during the 6 week non-training period. Following the 6 week non-training period, posttesting was completed for the NT group.

Data Analysis

For each variable an Analysis of Covariance (ANCOVA) was performed. The initial baseline measures of each individual was used as a covariate in the model. After adjusting for the initial measure the difference in groups was tested. Because three variables were tested a

Bonferroni correction yields a p-value of 0.0167 to determine statistical significance. All analyses were done using SAS version 9.2 (2008).

Results

After the treatment time period (12 sessions or 6-7 weeks) had elapsed, the following results were found.

40-yard sprint

Significant improvements in the 40-yard sprint were seen in the HS and ST groups when compared to the NT group. P-values were 0.0007 for the HS compared to the ST group and <0.0001 for the ST compared to the NT group. There was not a significant difference between treatment groups (HS & ST) ($p = 0.74$). Therefore, improvements were seen in the two treatment groups, HS and ST but not in the control group, NT.

Means and standard deviations for each of the groups are included in table 2.

Isometric extensor knee strength

Isometric extensor knee strength was improved in the ST treatment groups as compared to the NT group ($p = 0.0263$) and was nearly significant. There was no significant difference between the HS group and the NT group ($p = 0.51$), nor between the HS and ST groups ($p = 0.1482$).

Isometric flexor knee strength

In the analysis of isometric flexor knee strength no differences existed. There were no significant differences between the HS and NT groups ($p = 0.53$), nor between the HS and ST groups ($p = 0.67$), nor between ST and the NT groups ($p = 0.19$).

Discussion

The primary purpose of this study was to determine the effect of a body weight support (BWS) system while training on a high-speed treadmill training in a sport acceleration program (SAP) on an athlete's timed 40-yard sprint as well as the maximal isometric knee flexor and extensor strength during a sport acceleration program.

The high-speed treadmill training with BWS harnessing (HS) and the standard treadmill training group with no BWS harnessing (ST) produced significant decreases in 40-yard sprint times compared to a no sport acceleration or treadmill training program. Decreases in the 40-yard sprint times in the treatment groups (HS and ST) were -0.092 ±0.1 and -0.11 ± 0.11 respectively. SAP websites have stated a 0.2-0.4 seconds decreases in an athlete's timed 40-yard sprint.

In isometric flexor knee strength, the ST group showed a trend toward being significantly stronger than the NT group *(p = 0.026)*. The HS group showed no significant differences compared to the NT group *(p = 0.51);* neither did the ST group compared to the HS group *(p = 0.15)*. Isometric extensor knee strengths were not significantly different in any groups (HS compared to NT: *(p = 0.53)*), (HS compared to ST: *(p = 0.67)*, and (ST and NT *(p = 0.19)*. Strength changes are typically noted in SAP with treadmill training. We did not find an overall trend towards strength gains. It should be noted that the 12 session SAP provided for this study is typically an 18 session SAP. Had the 18 sessions been completed, those strength changes may have been more apparent. Strength gains are reported to be significantly visible after 6 weeks of training (Komi, 2003), hence the 12 sessions rather than the full 18sessions. Most participants completed the study in 6 weeks. This may be an explanation as to why no significant strength gains were reported. Another explanation may be that the training was not specific to strength gains, but rather focused on speed, agility, and quickness.

No studies were found to have defined the benefits of a BWS and high-speed treadmill training in a SAP. However, a number of studies conducted in the last decade focus on various aspects of a SAP or activities that are similar. The intent herein is to identify a safe and feasible exercise routine that will assist athletes in peaking in performance level just prior to a season.

Posttest sprint times for the HS group, as noted in table 2, were -0.092 ± 0.1 seconds slower than pretest scores, while posttest sprint times for the ST group were -0.12 ± 0.11 seconds slower, and NT sprint times were 0.17 ± 0.14 seconds faster. The average difference between the HS groups final speed and the NT group was 0.26 seconds and the difference between the ST and NT group was 0.29 seconds. The differences between these average final speeds may suggest a benefit of the sport acceleration program is to improve or maintain speed during a non-training season.

It should also be noted that these measured differences between treatment and control groups may suggest the treatment groups not only maintained but decreased their 40-yard sprint time. Hence, the HS and ST groups could be seen as having above the 0.20 second improvements typically reported by SAP.

Prior studies have shown that standard treadmill training without a harness in a SAP will improve athleticism, though no definition of athleticism was given (Shepherd, 2002, Schweigert & Frappier, 2002, L. E. Brown, Ferrigno, & Santana, 2000). Reported research on SAP, resisted sprint training, ground sprint training, and repeated sprint training vary in both tested measures and findings (Ross, 2009, Kristensen, 2006, Mero, 1992, Mero, 1986, Callister, 1988, Spinks, 2007, Zafeiridix, 2005, Bloomfield, 2007, Jovanovic, 2011). The lack of consensus in research may be explained by the many variances in tests and exercise routines between each study. Most, however tend to show a positive trend between a SAP and the chosen variables.

An interesting and unexpected finding of the study was the amount of overuse and other injuries occurring in participants. Participants in the ST group had a much higher rate (8 out of 13, or 62%) of shin splints and foot pain throughout the study than those in the HS (.09%) and NT group (0%). This may suggest the BWS used in the HS group provided the possibility to train at levels unattainable with a standard treadmill training program without incurring injury.

Beck reported that ground reaction forces (GRF) can reach 2.5 to 3 times the body weight with each stride (Beck, 2005). By removing weight from an athlete, it was understood that the sprinting would be less life-like. However, a benefit of the BWS is safety while training at higher speeds, and decreased ground reaction forces may have reduced the risk of developing overtraining related injuries. In the current study, participants found the BWS training to be somewhat uncomfortable while running due to the restrictions of the harness on the lungs; however, all stated that the safety of the harness was worth the discomfort and stated no desire to train without the BWS harness. The harnessing system may provide security and allow for sprinting at higher speeds.

Limitations

The population of interest for this study was limited to females (age 16 ± 1.19 yr) playing for a Utah County accelerated soccer teams. Suggested adaptations from this study are relevant only to accelerated female soccer players ages 14-18.

Many of the participants were still participating in practices and games. Adding the SAP training to the already rigorous training may have led to overuse injury and fatigue. Training outside of the study was as consistent as possible, though coaches altered many of the participants' training routines and schedules. These irregularities may have altered the current study's findings. A 12-session workout routine being completed over an average of 6 weeks may have been too little time to see significant differences in speed and strength.

Lastly, it was noted by the researchers herein that effort on the participants' part was often varied. Work ethic was notably different for each participant and may have had an effect on the results. Those with a higher ethic typically improved more overall than those that were less inclined to put forth necessary effort in training.

Conclusion

A Sport Acceleration Program (SAP) using a high speed treadmill training protocol and a body weight support harnessing system (HS) showed equal speed and improvements as compared to standard treadmill training with no body weight support harnessing system (ST). Both HS and ST groups were significantly faster than the no training, control group (NT). No significant changes were shown in quadriceps strength (isometric knee extensor strength) for any of the three groups, while hamstrings strength showed a trend toward significant increase in hamstring strength (isometric knee flexor strength). Participants in the ST group seemed to be more prone to overuse injuries than those in the HS and NT groups. Therefore, benefits determined by the researchers to using the HS training with BWS are that the un-weighted training provides safety and possibly less chance of overuse injury. More research is needed to determine whether injury rates and standard treadmill training versus BWS system training on a high-speed treadmill. The results of this study may increase understanding of the optimal sprint training protocol within a SAP. It may also suggest that training with a body weight support harnessing system allows for higher speeds of training that would be otherwise unattainable without overuse injury. This study may also provide coaches, athletes, trainers, and clinics an increased understanding of how to better train for competition.

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Table 1. 3-day treadmill training protocol

Treadmill training protocol			
	Day 1	Day 2	Day 3
Incline (%)	10	10	0
Sprint period (s)	10	5	5-8 x's forward, laterally right, backwards, & laterally left
Rest period (s)	40-60	20-40	20-30
Total time (m)	10	10	7-10
Other	N/A	N/A	90° turns Finish with 5 sec sprints for 2-3 mins

Table 2. A comparison (mean ± SD) of the 40-yard sprint time, isometric flexor knee strength (flexors), and isometric extensor knee strength (extensors)

	40 yard sprint	Flexors	Extensors
HS	-0.092 ± 0.1	-0.44 ± 6.03	11.97 ± 25.99
ST	-0.12 ± 0.11	3.44 ± 7.89	11.11 ± 18.93
NT	0.17 ± 0.14	-1.3875 ± 6.67	8.322 ± 23.77

*Significant difference *($p \leq 0.0167$)*

Figure 1. High speed treadmill with body weight support harnessing system

Prospectus

Chapter 1

Introduction

Training can produce dramatic changes for athletes in most team sports and has increased the emphasis on the improvement of speed and sprinting (Dintiman & Ward, 2003). Maximum running speed and acceleration are essential components in many field sports (Bangsbo, Nørregaard, & Thorsø, 1991). During the 1960s, the United States began researching ways to improve acceleration and stride length of Olympic sprinters. Training programs at that time did not consider the impact of acceleration; they looked only at the genetics of an athlete. However, since that time research and training camps have focused on sprint-assisted training, speed-strength training, and high-speed stopping, starting, cutting, and accelerating (Dintiman & Ward, 2003).

Competition levels continue to rise and performance experts are constantly being hired to develop high level and sport specific fitness programs for all ages. Professional athletes are not the only ones looking for a competitive edge; athletes at every level of competition are looking for ways to improve their abilities. Sports camps and training programs for young athletes are held around the country (L. E. Brown & Ferrigno, 2005). During these camps and programs athletes train in specific drills and techniques to enhance their performance. In particular, speed in the initial steps of a sprint is viewed as being significantly important during a game (Penfold & Jenkins, 1996) and is often a focal point of these programs. Though each program varies in method, the objective driving the programs is the same – improve an element of athleticism.

Speed, strength, agility, and power are essential aspects of Sport Acceleration Programs (SAP). A variety of methods are used to improve in performance. Plyometrics, strength training, agility and cone drills, and sprint training are the foundational basis of many of these programs.

High-speed treadmill running is also used to increase speed and strength in athletes. Athletes are taught and trained to run at high speeds on an incline in an attempt to increase leg strength and speed. Many SAP programs use the high-speed treadmill; however, very few to no programs use the body-weight support system while on running on the high-speed treadmill. This BWS system is usually a harnessing system that helps athletes train at higher velocities that would be otherwise unattainable in a safe environment.

High school athletes looking to play at a collegiate level strive to be at their peak in their junior and senior years in hopes of receiving scholarship offers. Many of these athletes, along with parents and coaches, are turning to SAP to provide the necessary intensity of training needed to compete at ever-increasing levels of play. These multi-week (varying from 6-12 week) workouts are thought to help athlete's get to peak physical fitness levels just prior to a season (Shepherd, 2002, Schweigert & Frappier, 2002, L. E. Brown, Ferrigno, & Santana, 2000).

Researchers exploring these acceleration programs and workouts show that the programs are successful in improving athleticism (Shepherd, 2002, Schweigert & Frappier, 2002, L. E. Brown, Ferrigno, & Santana, 2000). However, we found no research investigating the use of high-speed treadmills and BWS. There is a growing trend in the use of BWS systems and high-speed treadmill training in training programs and facilities. There is a need for randomized controlled studies to determine the effectiveness of a combination of BWS systems and high-speed treadmills during SAP.

Problem Statement

The purpose of this study was to determine the effect of a high-speed treadmill with the use of a body weight support system in a 6 week sport acceleration program on an athlete's velocity during a 40-yard sprint and maximal isometric knee flexor and extensor strength during a sport acceleration program.

Hypothesis

Participants in sport acceleration programs that utilize high-speed treadmills and BWS systems will have a greater improvement in their acceleration and speed than those that use a standard treadmill or do not incorporate a running program into the sport acceleration program.

Null Hypothesis

There is no difference between high-speed treadmill and BWS systems, standard treadmill training, and no sprint training in SAP.

Definitions

1. Sport Acceleration Program (SAP): A combination of strength base building, ballistic stretching and plyometrics, speed endurance training, footwork drills, and periodization that make up a training program just prior to regular season.
2. High-speed treadmill: A pulley system is used to reduce the weight of an athlete while he/she sprints at high speeds on a treadmill.
3. Plyometrics: The activity of rapid alternation of lengthening and shortening of specific muscle groups while resistance is continuously being applied to them.
4. Periodization: Plans for training based on a manipulation of the fitness components with the intent of peaking the athlete for the competitive season or varying health-related fitness training in cycles of harder or easier training.

Limitations

1. Subjects will be performing weekly training sessions together, thus it is impossible to blind them to the intent of the study. Subjects' knowledge of their hypothesized

improvements may influence the outcome of the results. Subjects were randomized in an attempt to counteract these effects.

2. The pretest may make participants more aware of or more sensitive to the treatment. Participants may also become more aware of their actual fitness level during the pretest, altering their perception of their future performance.
3. Motivation of athletes within each group may vary upon their anticipation of utilizing specific equipment.

Delimitations

1. Not all sports could be analyzed; therefore the researchers chose soccer.
2. Subjects were limited to female athletes on an accelerated soccer team with age ranges from 16-18.

Chapter 2

Review of Literature

Speed and strength are essential to performing well in sports. Athletes, coaches, and trainers are continuously seeking to improve athletic ability, speed, and power in athletic performance. As such, speed training has gained interest in recent years and has become a focus in high schools and training programs throughout the United States. There is a continuous need for athletes to improve in speed and power as competition levels continue to increase and the body's physiological responses to training are learned and improved. Many new ideas and theories have developed with modern improvements in understanding and utilization of training. In particular, high-speed treadmills with the help of body-weight support harnesses are being used in acceleration and speed training programs to improve running speed and power (L. E. Brown & Ferrigno, 2005; Schweigert & Frappier, 2002; Shepherd, 2002). Nonetheless, this literature review found little scholarly research on the benefit of this speed training technique.

This review of literature includes studies and research on body-weight supporting (BWS), linear speed and sprint training, treadmill training, slope and incline training, sport acceleration programs (SAP), measurements of strength, plyometrics, and the principle of overload. These topics were reviewed with the intent to find relationships with high-speed treadmill training and body-weight supporting during training.

Body-weight support systems are used to offset a percentage of body mass to provide an external support via a harness system. These body-weight support systems are being used for rehabilitation and locomotion in patient populations, including neural and stroke impairments, orthopedic injuries and pain (Franceschini et al., 2009; Franz et al., 2007; Hesse, 2008; Joffe, Watkins, Steiner, & Pfeifer, 2002; Mangione, Axen, & Haas, 1996; Ruckstuhl, Kho, Weed, Wilkinson, & Hargens, 2009). In a single-blind, randomized, controlled trial, Franceschini found gait training on a treadmill with BWS to be as effective as conventional gait training (Franceschini et al., 2009). In most studies there was no significant effect of treadmill training with or without body-weight support in stroke patients (Franceschini et al., 2009; Ruckstuhl et al., 2009).

Ambulation has been shown to change with BWS. During a body-weight supported treadmill test, step length was shown to increase, while cadence decreased. Upper body restriction is greater with higher levels of support, as well as a smaller displacement of the center of mass, decreased foot-contact time, and decreased hip-, knee-, and ankle-angle ranges. Various harnesses used in body-weight supporting were found to be equal in variations regardless of the harness used to suspend subjects while running (Millslagle, Levy, & Matack, 2006).

Physiological differences during BWS were found to be no different than conventional treadmill walking and running. Gas exchange variables and exercise capacity are not effected by 15% BWS in adults without impairments, while maximal tidal volume is lowered (MacKay-Lyons, Makrides, & Speth, 2001).

In more recent years, the BWS system has been introduced into the sport and athletic performance field. It is believed that while the harness supports the body during running, the athlete can sprint at higher speeds because of the amount of mass the body must support and carry through the sprint is less despite the fact that the body is producing the same force through the sprint. However, no primary research was found regarding the use of the BWS systems in athletic performance.

Running speed can be by determined by calculating the time necessary to cover a predetermined distance. Linear speed is typically measured with a timed sprint over a predetermined distance (Delecluse et al., 1995; Delecluse, 1997; Frishberg, 1983; Harrison & Bourke, 2009; Ross et al., 2009; Smirniotou et al., 2008; Spinks, 2007; Young, McLean, & Ardagna, 1995).

Presently, there are two leading modes of training for speed and sprint training: ground based resistive training and treadmill training (Ross, R. E., Ratamess, N. A., Hoffman, J. R., Faigenbaum, A. D., Kang, J., & Chilakos, A. (2009). Resisted sprint training has been used to increase strength and power in lower extremity musculature with intent to increase stride length and reduce foot-ground contact (Spinks, 2007). Similarly, treadmill sprint training can significantly increase sprint velocity, power, and one repetition maximum (Ross, Ratamess, Hoffman, Faigenbaum, Kang, & Chilakos, 2009). Research indicates that both incline and resistive ground-based training decrease sprint start speed (Myer, Ford, Brent, Divine, & Hewett, 2007).

Runners have long used treadmill training during cold weather as well as to utilize the control of incline and speed. Treadmills are also used for conveniences of running in a relatively fixed position for analysis of running technique. However, there is an assumption that treadmill training (both walking and running) is similar to over ground locomotion. The research is very inconsistent on whether the two types of running are synonymous. Some studies support, while others retort training on a treadmill (Frishberg, 1983; Nelson et al., 1972; Nelson, Dillman, Lagasse, & Bickett, 1972; Nigg, De Boer, & Fisher, 1995). Nigg, De Boer, & Fisher (1995) believes the differences between over ground and treadmill running could be divided into either systematic or subject dependent components. Treadmill running has also been reported to produce biomechanical and kinematic differences from over ground running (Nelson et al., 1972; Nigg, De Boer, & Fisher., 1995). Regardless of these reported differences, Ross, Ratamess, Hoffman, Faigenbaum, Kang, & Chilakos (2009) found that a 7-week treadmill sprint-training program enhanced over ground sprint performance.

Frappier (2002), a considered expert on elite athlete training, states that a benefit of treadmill training is seen in the ability to manipulate incline and speed to obtain neuromuscular responses greater than what an individual can do over ground. When fatigue sets in during over ground running, an athlete simply slows down. During treadmill training; however, the athlete must continue to run at the given pace regardless of fatigue levels (Schweigert & Frappier, 2002; Shepherd, 2002).

Frappier's theory supports the overload principle described by Allsen (2009) which states that improvement within a system is brought about by supplying a greater load than what the system is accustomed to bring about improvement. Thus, as the systems adjust to greater loads, the capacity to perform work increases.

Sloped surfaces and incline running have been recommended by some researchers to assist athletes in increasing running velocity on level surfaces. Paradisis & Cooke (2006) found the effects of sprint training on sloping surfaces (3 degrees) to produce significant increases in maximum running velocity. The study included uphill, downhill, and a combined uphill and downhill training. The combination of up and downhill training was found to be the most beneficial, though uphill and downhill training were also found to help increase velocity of runners. Slawinski. Dorel, Hug, Couturier, Fournel, Morin, & Hanon, (2008), however, found incline running to decrease running velocity at slower velocities. Differences were attributed to the slower velocities to a lower level of activation of the hamstring muscles. Biomechanical differences between high-speed incline and level treadmill training were found, though muscle activation during swing and stance phases was enhanced in the hip extensors (Swanson & Caldwell, 2000).

The validity of acceleration programs is primarily based on the Frappier Acceleration Training program. The acceleration program is generally found to improve athletic skill and ability (Shepherd, 2002). Frappier's studies consist of 6-8 week training programs that include incline running, plyometrics, footwork drills, and agility training (Hanssen, 2002); all research performed on these acceleration programs are done by Frappier or his associates. Neither primary nor scholarly research was found to specifically analyze the use of the high-speed treadmills in these training programs. There was a general paucity of foundational information regarding these training programs; this review of literature found opinion, theory, pro/con statements, and poster presentations on both the acceleration programs and the treadmills used (Brown, Vescovi, & VanHeest, 2004; Brown & Ferrigno, 2005; Schweigert & Frappier, 2002; Shepherd, 2002; Hanssen Meyer, Everett, Walker, 2002).

Strength is typically defined as the maximum amount of force that can be exerted against a resistance and is a fundamental part of optimal physical performance (Guy, 1996). There are three strength tests typically used in research to determine an individuals strength levels. Isokinetic tests control the speed of movement through a range of motion, isotonic tests use a full range of motion and a maximal weight, while isometric motions require maximal push or pull without movement (Guy, 1996). Jameson, Knight, Ingersoll, & Edwards, (1997) stated it doesn't matter which measurement is used to predict vertical jump, but suggests using a battery of tests to determine functional abilities. In one study, maximal isometric squat strength was measured before and after 10 weeks of both sprint and plyometric training. Associated changes in force were significantly different from pre value forces for sprinting ($p<0.0167$). Significant differences were also seen in the sprint group when compared with plyometric and control groups (P<0.05) (Markovic, Jukic, Milanovic, & Metikos, 2007).

The angle at which isometric testing being performed is known to affect force measurement. For the sake of testing convenience, isometric strength is usually measured at only one angle in the range of motion. The best angle to use for comparison with performance scores is the one that produces peak force (Murphy, Wilson, Pryor, & Newton, 1995).

Plyometrics are movements in which a muscle is loaded and contracted in rapid sequence. In most sports the ability to produce quick force dynamically is of utmost importance (Sanborn, 2010). Plyometric exercises have been shown to be beneficial to sprinting speed and athletic performance (de Villarreal, Kellis, Kraemer, & Izquierdo, 2009; Saunders et al., 2006; Turner, Owings, & Schwane, 2003). A study looking at the effects of sprinting and plyometrics on muscle function and athletic performance shows evidence that sprint training and plyometric training provide similar results when determining athletic performance. The coefficients of variation and intraclass correlation coefficients for the study's chosen tests ranged between 1.9 to 4.1% (in a 95% confidence interval, 1.7–4.8%) and between 0.91 and 0.96 (95% confidence interval, 0.88–0.97) indicating high absolute and relative reliability (Markovic et al., 2007).

Key to achieving optimal adaptations and explosive power or "speed strength" from plyometric training are technique, progression, and periodization (Sanborn, 2010). Commonly used plyometric exercises include the squat jump, counter-movement jump, repeated jumps, and standing jumps (Sanborn, 2010; Smirniotou et al., 2008). It has been determined that 6 weeks of plyometric training in regularly trained individuals will improve running economy (Turner et al., 2003). Wilson, Murphy, & Walshe (1997) found that a high strength base does not need to precede plyometric training to invoke performance gains.

Chapter 3

Methods

Participants

25-33 female high school soccer players (ages 16-18) will be recruited for this study. All subjects will be physically active and participating on local (in Utah County) accelerated soccer teams. We did not control for running training prior to the study. Due to the variety of exercises required in this study participants will be free of all extremity and spinal injuries for the past 6 months. Prior to any testing subjects and parents will complete a pre-participation questionnaire and sign an informed consent approved by the Institutional Review Board at Brigham Young University. Randomization of subjects will be done through a random draw of slips of paper indicating group number. There will be equal opportunity to be randomized into each group.

The menstrual cycle was determined a part of a normal female life and will not be taken into consideration during this study. Any alteration in motivation levels will be controlled for by not giving results to subjects until after the study is complete.

The sample chosen for this study limits the generalizability to females between ages 16-18 years old who are on accelerated soccer teams within Utah County with no known current or previous injuries will be used. The study's results may be generalized to this sample.

Design

The study's design is 2x3x2 factorial design examining the effect of a high-speed treadmill on an athlete's acceleration improvements during a given sport acceleration program. A standardized sport acceleration program (SAP) at Central Utah Clinic will be performed by all participants. In addition to the SAP, all subjects will be randomly placed into 1 of 3 groups: (1) training on a high-speed treadmill with body-weight supporting (HST), (2) training on a standard treadmill with no body-weight support (STT), and (3) a control group with no sprint training program (NR).

Confounding variables may include training done outside of the study by participants; therefore, participants will agree to maintain level of activity outside of the study. The use of performance-enhancing substances during the study will be screened for in pre-participation questionnaire.

Procedures

For clarity, the procedures and methodology section is separated into 4 stages. Central Utah Clinic's Acceleration Program specialist, Brett Mortensen, will recruit subjects; he will speak to the local accelerated soccer coaches and parents and asking for interested teams and individuals to participate in the study. Training in the SAP at Central Utah Clinic is typically $200-$400 per person. Participants in this study will participate in the SAP, free of charge, with the understanding that groups are randomized and utilization of the high-speed treadmill is not guaranteed. Those subjects not participating in the HST group will be given an opportunity to use the treadmill 6 times following the study.

Carie Eastman and Brett Mortensen have been trained to administer the SAP and will be the only ones conducting the high-speed treadmill portion of the study.

<u>Stage 1: Pre-study information session</u> During this session, a more detailed explanation of the study will be given to all interested subjects. Consent forms and pre-participation questionnaires will be completed and a treadmill familiarization training meeting will be given to those interested.

Participants will be familiarized with the 2 types of treadmills (high-speed and standard) being used in the study. One individual not affiliated with the study will demonstrate the use of the high-speed treadmill. Interested participants may choose to review the pretesting protocol for the SAP (Appendix 1).

Potential participants will fill out the pre-participation questionnaire. We will review the pre-participation questionnaire according to inclusion and exclusion criteria to create our sample pool. From this pool, we will draw 33 random names to participate. These will further be randomized into one of three research groups. Participants will complete consent forms and pretesting measurements (Appendix 1) including a 40-yard sprint. Using a strain gauge, participants' knee extensor and flexor isometric strength will be measured in a seated position with knees at a 90 degree angle. Participants will be seated on physical therapy table and stabilized via stabilizing straps across upper thigh. Pretesting measurements of the 40-yard sprint will be completed in a level parking lot of Central Utah Clinic after a 2-3 minute pre-stretching routine.

Stage 2: Pretesting data collection Participants will be randomized into one of 3 groups: (1) High-speed treadmill training (HST), (2) Standard treadmill training (STT), or (3) Non-running control group (NR) for the 12 session training period of the study.

Stage 3: Training Period Participants will complete the 12-session SAP at Central Utah Clinic. Strength base building, flexibility, plyometrics, speed endurance training, footwork drills, and periodization are standard for the SAP and will be performed by all three groups (Appendix 2).

The HST group will use the high-speed treadmill during each training day in addition to the standardized drills for specified testing days. Beginning and maximal velocity for each session will be recorded (Appendix 3).

High-Speed treadmill training for group 1			
	Day 1	**Day 2**	**Day 3**
Incline (%)	10	10	0
Sprint period (s)	10	5	5-8 x's each direction
Rest period (s)	40-60	20-40	20-30
Total time (m)	10	10	7-10
Other	N/A	N/A	90° turns Finish with 5 sec sprints for 2-3 mins

Table 1: Days 1-3 of HST training program for group 1

HST sprint training consists of a ten minute sprint training program; the participants are harnessed into a body-weighting support system. The harness will stay in place throughout the 10 minutes and can assist participants in feeling comfortable and steadied; it also helps with getting on and off the treadmill safely. There are three training series that will be used in the 6-week program for the HST sprint training group (Table 1).

Participants will warm up on a standard treadmill at 0% incline at 8 mph for 3 minutes. Participants will then complete 10-second sprints with 40-60 second rests for a total of 10 minutes. Participants will begin at a comfortable sprint pace (8-11mph) at a 10% incline. After the first 10 second sprint, the velocity of the treadmill is increased in increments according to the ability of the participant. According to a pilot study, increases are typcially made in increments of 0.5 mph to 2.0 mph. This increase is dependent upon the beginning sprint pace and the advancement in the program. A compressor unweights the athlete approximately 20% via the harnessing system after which the treadmill is brought up to the beginning speed for the 10 second sprints. Beginning sprint speeds will be individualized for each participant and determined in the pretesting and familiarization stage of the study. After the participant has let go of the hand rail, the 10 second sprint begins. The 40-60 second rest period begins immediately after the participant steps off the treadmill. Treadmill velocity is increased according to toleration by the participant within each session and throughout the 12 session program.

Because the participant is wearing a harness falling off the back of the treadmill is not possible. However, the runner will move further back on the belt of the treadmill as the velocity increases. Therefore, fatigue level will be determined by position on the treadmill. The velocity prior to the point at which the participant cannont maintain proper foot placement on the treadmill will be considered maximal velocity for that session.

The final 2 sprints of each session will be performed at 5 and 0% incline respectively with the athlete running at her determined maximal velocity.

The second sprint series consists of 5 second sprints; these will be performed in a similar manner to the 10 second sprints. The only change is time of sprints and time of rest between sprints, sprint times are 5 seconds, while rest time is 40-80 seconds.

The final series of sprint training for the HST group consists of 360° lateral training. Participants are again harnessed and instructed to turn 90° according to verbal cues of "left" or "right" given by researcher while sprinting on the treadmill on a 0% incline. The 90° turns are repeated until participant has received 4 verbal cues to turn another 90°. The participant will now be facing forward. A reversal of direction (if told to turn left first the subject will now start right) will then be given to the participant, after which the subject will then step off the treadmill. Once the participants have performed 5-8 turns in both directions, they will complete 5 sec sprints at 0% incline for 2-3 more minutes. This routine will continue, with increasing speeds, within each session as well as throughout the 12 session program as per ability of the participant. Once the participants have completed the 3 series, they will be repeated.

The STT group will run on a 8-10% incline without a harness at 8-10 mph using the same times as the HST group. Beginning sprint speeds and rest periods will be individualized for each participant and determined in the pretesting and familiarization stage of the study (Table 2).

Standard treadmill training for Group 2			
	Day 1	**Day 2**	**Day 3**
Incline (%)	8-10	8-10	0
Sprint period (s)	10	5	5-8 x's each direction
Rest period (s)	40-80	20-60	20-30
Total time (m)	10	10	7-10
Other	N/A	N/A	90° turns Finish with 5 sec sprints for 2-3 mins

Table 2: Days 1-3 of standard treadmill training program for group 2

The NR group will not perform a sprint-training program in the SAP but will only complete the standardized drills. Running levels, drills, and times will be recorded during each training session.

<u>Stage 4: Post training data collection</u> After 12 session training period, all participants will repeat the pretest skills tests.

<u>Stage 5: Analysis</u> A comparison of the mean values from pre- and post-training will be determined for all skills including speed, strength, flexibility, and power. Measurements of acceleration improvements will be measured and analyzed using a simple ANOVA.

An ANOVA test will be performed to see if there is a difference between groups. To determine where the difference is between groups, Tukey's HSD post-hoc test will be performed. The means and standard deviations will be reported. A table will be formulated listing the athlete's height, weight, soccer position, age, and year of participation in the accelerated soccer program.

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Appendix A-1. Central Utah Clinic's Pretesting Protocol for SAP

Central Utah Clinic Athletic Enhancement (SAP) Pre-Test

Name: ______________________________ Date: _______________

Sport: _____________ School: _____________ DOB: ______________

Sprints

	pretest	*posttest*
40 yd		
20 yd		

Lateral Shuffle

	pretest	*posttest*
Right (s)		
Left (s)		

Starting, Stopping, Cutting

	pretest	*posttest*
Right (s)		
Left (s)		

NASE Repeated Sprints 30yd/30 sec rest

Trial	Pretest (s)	Posttest (s)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

	Pretest	Posttest (r/l)
Active supine knee extension (degrees)	Right: Left:	Right: Left:
Side Planks	Right: Left:	Right: Left:
Iso-Lexr	sec	sec
Iso-Abs	sec	sec
Sitting Isometric hamstrings	lb	lb
Sitting Isometric Quadriceps		
Triangle test		

Appendix A-2: Central Utah Clinic's SAP Routine

Name: ___________________________ Start date: ____________________ End Date: ______________ _ Group: 1 2 3

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12
Warm Up Stretches include: High Knees (x3), Butt kickers, Inch worm, Hamstring stretch, & Cranes												
Warm Ups												
Exercises												
Ladder Drills (9-12)												
Dot Drills												
Bosu Ball Planks/board abs												
Iso-lexr												
Shuttle Jumps												
Plyometric Maniacs												
MedBall Sit-ups (X2)												
Monster Bands												
Treadmill 10/5/360												

Appendix B

Raw Data

Test	group	subject #	age	Wt (lb)	Ht (in)	40 yd	Quads	Hams
pre	1	6	15	125	64	**6.09**	**93.10**	**28.35**
post	1	6	15	125	64	**5.97**	**107.45**	**27.20**

pre	1	7	15	150	59	**6.06**	**104.70**	**13.65**
post	1	7	15	150	59	**6.00**	**100.60**	**9.75**
pre	1	8	17	110	65	**5.71**	**76.60**	**49.50**
post	1	8	17	110	65	**5.83**	**82.45**	**37.90**
pre	1	9	15	113	65	**5.81**	**87.55**	**35.00**
post	1	9	15	113	65	**5.88**	**81.25**	**36.75**
pre	1	10	15	120	68	**6.37**	**103.50**	**36.55**
post	1	10	15	120	68	**6.22**	**79.05**	**45.75**
pre	1	11	15	130	65	**6.12**	**116.25**	**30.50**
post	1	11	15	130	65	**6.03**	**102.00**	**32.35**
pre	1	13	17	140	66	**5.91**	**80.45**	**31.35**
post	1	13	17	140	66	**5.78**	**102.55**	**34.40**
pre	1	28	17	112	63	**5.76**	**82.20**	**26.60**
post	1	28	17	112	63	**5.51**	**99.85**	**32.30**
pre	1	14	17	130	66	**5.65**	**77.00**	**37.00**
post	1	14	17	130	66	**5.50**	**140.65**	**28.00**
pre	1	15	15	120	68	**6.06**	**82.40**	**30.50**
post	1	15	15	120	68	**5.91**	**91.75**	**30.40**
pre	1	19	14	115	63	**5.88**	**50.70**	**32.95**
post	1	19	14	115	63	**5.78**	**98.70**	**32.30**
pre	2	1	15	117	65	**5.84**	**104.25**	**42.00**
post	2	1	15	117	65	**5.78**	**108.75**	**42.45**
pre	2	2	16	125	67	**5.56**	**113.35**	**43.15**
post	2	2	16	125	67	**5.56**	**120.40**	**38.90**
pre	2	3	17	123	62	**5.85**	**111.60**	**33.60**
post	2	3	17	123	62	**5.72**	**91.30**	**39.80**
pre	2	4	17	150	66	**6.94**	**110.75**	**21.25**
post	2	4	17	135	66	**6.64**	**109.05**	**31.05**
pre	2	5	16	130	64	**5.87**	**93.05**	**32.05**
post	2	5	16	130	64	**5.84**	**128.05**	**47.40**
pre	2	12	17	130	61	**5.47**	**54.10**	**34.80**
post	2	12	17	130	61	**5.50**	**70.40**	**26.75**
pre	2	26	17	133	67	**5.27**	**158.40**	**43.20**
post	2	26	17	133	67	**5.25**	**156.80**	**49.85**
pre	2	27	17	106	63	**5.99**	**118.85**	**25.50**
post	2	27	17	106	63	**5.76**	**117.70**	**36.45**
pre	2	29	17	190	67	**5.94**	**105.20**	**48.75**
post	2	29	17	190	67	**5.94**	**140.70**	**41.10**
pre	2	17	17	137	62	**5.69**	**88.50**	**32.65**

post	2	17	17	137	62	**5.66**	**89.40**	**36.85**
pre	2	18	17	125	62	**5.83**	**72.60**	**20.95**
post	2	18	17	125	62	**5.58**	**120.60**	**33.60**
pre	2	23	17	123	65	**5.91**	**86.80**	**39.05**
post	2	23	17	123	65	**5.61**	**90.05**	**43.10**
pre	2	30	14	120	62	**5.90**	**90.90**	**32.40**
post	2	30	14	120	62	**5.87**	**109.55**	**26.80**
pre	3	32	17	130	66	**5.66**	**89.90**	**23.10**
post	3	32	17	130	66	**5.80**	**108.00**	**16.65**
pre	3	33	16	140	64	**5.68**	**74.90**	**21.90**
post	3	34	16	140	64	**5.77**	**78.65**	**27.40**
pre	3	35	17	115	63	**5.07**	**69.75**	**26.15**
post	3	35	17	115	63	**5.21**	**53.10**	**14.40**
pre	3	36	14	120	66	**5.56**	**66.05**	**21.95**
post	3	36	14	120	66	**5.71**	**63.85**	**28.90**
pre	3	37	14	112	64	**5.65**	**75.90**	**21.45**
post	3	37	14	112	64	**5.80**	**89.35**	**24.75**
pre	3	38	14	125	66	**5.53**	**44.05**	**44.05**
post	3	38	14	125	66	**5.71**	**104.10**	**38.20**
pre	3	39	17	150	66	**6.81**	**110.75**	**29.70**
post	3	39	17	150	66	**6.78**	**110.75**	**25.20**
pre	3	25	17	145	65	**5.50**	**77.50**	**20.85**
post	3	25	17	145	65	**5.94**	**67.60**	**22.55**