The Effect of Targeted Force-Velocity Training on Jump Performance in Elite Sub Academy Rugby Players

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A project submitted in part fulfilment of the requirement for the BSc in Sports Coaching and Performance

April 2018

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Statement of originality and ownership of work

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Acknowledgement

Firstly, I would like to thank the lecturers of BSc in Sports Coaching and Performance who have assisted in my learning with regards to this submission, in particular my advisor Richard Bolger for his guidance throughout this process.

I would also like to thank Munster Rugby for the use of their facilities and equipment throughout this study and the approval of conducting research within their academy.

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Abstract

Overview: There is little research comparing the effect of combined force-velocity training programs on the elite athlete population, therefore this study looked to compare a force-velocity training intervention to standard heavy load strength training in the population of elite sub academy rugby players. **Methods:** 18 male rugby players age (yr.) (*M* = 16.94, *SD* = 0.80), height (cm) (*M* = 185.91, *SD* = 10.88), weight (kg) (*M* = 87.23, *SD* = 16.81) participated in this study. Participants were assessed on jump performance height, at weighted increments, to produce force (N/kg), velocity (m/s) and maximum power (w/kg) measures in conjunction with force-velocity curve profiles. Participants were then randomised to either force-velocity training (FVG) (*n* = 9) or heavy load training (HTG) (*n* = 9) of the lower body and were reassessed following completion of a five-week training intervention. **Results:** Significant differences were found in the FVG maximal power from pre to post test (p = 0.0007) with the HTG showing significant difference in force from baseline (p = 0.0009). No other significant changes were found within group testing. Between group percentage change comparing of variables showed no significant difference in training intervention. **Conclusion**: The findings from this study suggest that a combined force-velocity training program can increase maximal power (w/kg) over a five-week period in elite sub academy rugby players and may be more beneficial for increasing maximal power compared to a heavy load training program. Force capacities are increased by training at the high force end of the force-velocity curve through a heavy load training program.

Chapter 1. Introduction

Resistance training is a vital component of Rugby which requires maximal outputs of strength (force), power (force * velocity) and speed (velocity) throughout the game (Cunningham et al., 2016). Many studies show the importance of improving overall strength in rugby players (Appleby et al., 2012, Corcoran and Bird, 2009) and other research on the velocity and running performance needed by such athletes (Lockie et al., 2014 and Gabbett, 2006). The research pertaining to what the most effective program for resistance training for performance measures of force, velocity and power account for contrasting opinions. Heavy load weight training has been associated with superiority in increasing these variables in certain research (Argus et al., 2012; Moss et al.,1997; Tricoli et al., 2005) while training with lighter loads was shown to achieve greater changes to these performance measures in contrasting research (McBride et al.,2002; Ramírez et al., 2015; González-Badillo et al., 2015). Despite the inverse relationship between force and velocity, studies on the combined training approach of heavy-light loads has been conducted on populations of recreationally trained subjects (Cormie et al., 2007; Harris et al., 2000; Kotzamandis et al., 2005) with results showing this method to be superior to traditional program comparison. However, little research on this combined approach has been implemented with elite athletes. This study looks to address the comparison and effect of a targeted force-velocity program to standard strength training on elite sub academy rugby players.

Chapter 2. Literature review

2.1 Introduction

Professional rugby players exhibit high levels of strength, power and speed (Argus et al., 2012; Roberts et al., 2008). Strength and power capabilities may be the discriminating factor between professional and non- professional players. Argus et al. (2012) studied the differentiating characteristics between these levels at semi-professional, academy and professional rugby players. The findings suggest there was no significant difference in strength levels relative to body weight in box squat between groups. However, in testing of loaded jump squat the professionals produced much greater power outputs. Concluding that professional players possess greater ability for exerting high levels of force at greater velocities and may be one of the determinants of playing ability between groups.

2.2 Heavy Load training

Moss et al. (1997) investigated the effects of maximal effort strength training with different loads in the elbow flexor among physical education students. Three groups trained with different loads of one repetition maximum (1RM) (G90= 90%, G35= 35%, G15= 15%). The results established that 1RM increased in all groups with G90 recording the largest increase. The load-power and load-velocity relationship was also investigated. The load-power test indicated that all groups increased in power at loads specific to their training load while the G90 group increased power in all loads tested, with a larger increase at the higher testing loads. The load-velocity relationship displayed similar results with all groups increasing relative to training weight and the G90 group increasing velocity at all weights. These results suggested that the G90 group experienced the greatest shift to the right in force-velocity relationship of the muscle tested. This study proposes that training at near maximal loads causes an increase in power over a wide load range which would indicate in order to enhance velocity and power across the force velocity profile, training with heavy loads is preferable. A limitation to the study would be the standardised use of the non-dominant arm for training. While each participant trained using one arm the other arm acted as a control for comparison to pre-testing results, no account was taken for initial adaptation which could have been a factor while training only the non-dominant arm, which, could have skewed results towards a greater improvement from pre-testing scores.

Similarly, Argus et al. (2012) suggested heavy load training to be superior to light load training in a study on jump performance using rugby union players. Eighteen players were assigned to either a high load (strength-power) or low load (speed-power) group over a four-week intervention program. Pre and post testing was performed on bodyweight countermovement jump, bodyweight squat jump, 50 kg countermovement jump, 50 kg squat jump, broad jump, and reactive strength index depth jump. The intervention program consisted of each group performing similar exercises with different percentages of 1RM. The strength-power group trained between 80-95% on heavy loading days versus the speed- power group 55-65% throughout the four weeks. The results indicated that the high load group performed superiorly with greater improvement in 50kg Countermovement jump, 50kg squat jump and broad jump with no significant between group differences in body weight countermovement jump, body weight squat jump or depth jump. However, the strength- power group did produce small increases in these over the speed- power. Peak force improved in the strength- power group from baseline with 12.1% in the 50kg counter movement jump and 26% in the squat jump and peak velocity in the 50kg counter movement jump of 7.7%. The speed-power group were recorded as having trivial improvements in peak force measures with a small decrease in peak velocity in the 50kg squat jump. Thus, concluding the use of heavy load training for improvement in jump performance over light load training.

In contrast, Jidovtseff et al. (2011) investigated the ability of the load-velocity relationship to accurately predict a bench press one repetition maximum, suggesting that measuring peak velocity does not accurately represent the person's ability to move a load through the whole concentric phase of a lift and that mean velocity is a better indication of ability for a field sport athlete. The standardised use of 50kg for weighted jumps could significantly impact results depending on the athlete’s body weight and subsequently on the training intervention that is undertaken. Considering this study was conducted on rugby players of all positions, the positional characteristics of these players (weight, height, muscle mass) is of importance and was not account for (Duthie et al., 2006; Olds, 2001) therefore it could have been more appropriate to use a % of body weight or % of 1RM for these lifts to fully determine the impact of the training interventions.

Tricoli et al. (2005) compared the effect of two training programs specifically explosive weightlifting and squats versus light load plyometrics and squats in 38 physically active males. Pre and post testing included squat jump, counter movement jump, 10m sprint 30m sprint, and half squat. Following an eight-week training intervention pre and post test scores were compared and resulted in the weight training intervention group producing superior results in the squat jump and 10m sprint. Both groups increased counter movement jump height with the weightlifting group showing greater improvement, both groups also increased running speed over 30m. The plyometric training group achieved greater scores in the half squat with regards to between group comparison. This concluded that heavy lifts and weightlifting enhances lower body power performance greater than plyometric exercise and squat training. In view of the relatively inexperienced weight training of the individuals tested the greater improvements from the strength group could be due to an initial training response to weight training in general and to Olympic lifts and not the specificity of the training type. If this study was conducted on elite strength training athletes it may not produce the same results as this stimulus may not be enough to result a change (Baker, 1996). Conducting similar research on elite strength trained athletes and the response to this stimulus may have greater impact on which training intervention is more significant.

2.3 Light Load Training

A study on the effect of an eight-week training program with heavy versus light load jump squats on different performance measures was conducted by McBride et al. (2002) on 26 athletic males. The heavy load group trained with 80% of their 1RM while light load trained 30% of 1RM of back squat. Pre and post testing on 20m standing start sprint and jump squats at different loads of 30%, 55% and 80% of 1RM recording peak force, peak velocity, peak power and jump height for all jump loads. The group training at lighter loads showed significant increases in peak velocity for all squat jump loads which showed overall improvements in velocity capabilities regardless of the weight. This group also illustrated increased peak power and increased peak force for all weight increments and a small 1RM weight improvement. In the 20m sprint there was a decrease in times. In comparison the heavy load training group increased peak power. Peak force was significantly greater in post testing of this group across all jump squat weights and increased greater in 1RM but showed a decrease in velocity capabilities and performed slower over 20m sprint then pre- testing scores and the light load group post-test. The results of this study would suggest that training with lighter loads had a greater overall performance effect on different variables associated with game demands (sprinting, contact, acceleration) for players. While examining the protocol for squat jump testing it was stated that participants were cued to squat down and jump immediately. This would change the jump from a squat jump using concentric muscle contraction to a counter movement jump which uses the stretch shortening cycle which would affect scores due to the different capacities athletes may hold to utilise this more effectively than others being tested. It could also affect 20m sprinting ability, as sprinting uses the stretch shortening cycle, which could have been potentiated by the use of counter movement jumps and not by the training intervention (Fletcher and Jones, 2004).

Ramírez et al. (2015) and González-Badillo et al. (2015) both studied the effects of the introduction of a velocity-(speed) based resistance program on performance in soccer players. Ramírez et al. (2015) suggested that lower body power production in soccer players improved by the introduction of a 10-week velocity-based resistance training programme consisting of sets of half squat at a fixed load and set velocity. Similarly, González-Badillo et al. (2015) studied the effects of maximal velocity-based resistance training program over a 26-week period in 44 elite youth soccer players suggesting that velocity- based resistance training greatly improved performance on leg strength, vertical jump, 20m sprint and MAS testing. In the study conducted by Ramírez et al. (2015) the athletes trained based on velocity of concentric phase and tested concentric phase half squat force, velocity and maximum power both pre and post intervention. The results showed increased force, velocity and relative power to weight ratio from pre-testing scores. The author proposed that it is not deemed necessary to increase external load (force) to improve power outputs for athletes.

The intervention group in González-Badillo et al. (2015) comprising of under 16s and under 18s males completed a program focusing on high velocity on squats, counter movement jumps, sled pulls, hurdle jumps and box jumps along with soccer training. The control group (under 21s) continued normal soccer only training. The pre-test scores rated the under 21 performance superior to the intervention group, however, following the training intervention, the post testing results indicated that the intervention group improved and surpassed the scores of the control group in all tests on leg strength, vertical jump, 20m sprint and MAS testing.

While Ramírez et al. (2015) and González-Badillo et al. (2015) both reported that velocity- based resistance training greatly improved performance (p = 0.000, p = 0.001), the participants in both studies had no previous weight training experience and therefore improvements resulting from initial gains cannot be ignored. Much of the research surrounding positive effects of velocity-based training on performance measures has also studied untrained participants (De Villarreal et al., 2009; Toumi et al.,2004). Also, while these studies suggest that maximal velocity-based resistance training greatly improved performance on match related tasks and demands of a soccer player no comparison of this training type with other forms such as resistance training at higher loads, which from other research (Tricoli et al., 2005) has shown to improve all of these factors was discussed. Therefore, while demonstrating the positive effect of velocity- based training there is no discussion regarding other forms of training for improvement in performance.

While studies have shown heavy load (Argus et al., 2012; Moss et al., 1997; Tricoli et al., 2005) or light load (González-Badillo et al., 2015; McBride et al., 2002; Ramírez et al., 2015) as optimal for improvements in performance the specificity of results indicates a trend towards greater improvements in the force end of the curve for heavy and the velocity end of the curve for light loads. A combined approach of both heavy and light addressing each end of the force velocity curve should be optimal for performance improvements across all loads to insure they are produced with the greatest velocity possible (Kirby et al., 2010). Programming training with the intention to move loads with the highest velocity capable is important for improvement in power output with regards to strength training and to drive adaptations to training in athletes (Behm and Sale, 1993; Cormie et al., 2011; Crewther et al., 2005).

2.4 Combined approach

Cormie et al. (2007) and Harris et al. (2000) investigated the force-velocity relationship and its influence on training variables of strength 1RMs and jump performance. Both studies investigated a comparison of a combined training approach of high force and high velocity resistance training with traditional strength only or velocity only programs. Cormie et al. (2007) examined the difference in two training programs over 12 weeks, namely power versus strength- power on relative peak power, peak force, peak velocity and jump height across different loads (BM, 20kg, 40kg, 60kg and 80kg) on jump squat. The power group trained body weight jump squats targeting the velocity end of the curve while the strength- power group performed the same exercise with less sets while also incorporating maximal strength sets of back squats at 90% of 1RM allowing training to target both the high force and high velocity areas of the curve. The results of testing showed that the power training group increased peak power at body weight and 20kg while the combined training group improved peak power at all loads tested, this was also true of jump height which indicated improvements for the power training group at lighter loads only whereas the combined group improved at all loads. Harris et al. (2000) considered all training types by comparing high force, high velocity and combined training methods over nine weeks in forty-two men with testing carried out on a wide variety of athletic performance variables; 1RM parallel squat, 1RM ¼ squat, 1RM mid-thigh pull, vertical jump, vertical jump power, 30m sprint, 10-yard shuttle run and standing long jump. Each group exhibited improvements in tests relative to training load used. The high force group improving 1RM squat, ¼ squat and mid-thigh pull and the high velocity group improved 1/4 squat, mid-thigh pull, vertical jump and standing long jump. Subsequently, due to training at both loads, the combined group improved in all the above tests and improved vertical jump power and 10-yard shuttle also.

Cormie et al. (2007) and Harris et al. (2000) concluded that in order to improve across a wide variety of sporting requirements a combined approach to training produced the most effective results. While these studies underpin the idea of a combined training load of both force and velocity training, both studies populations consisted of recreationally trained males. While the belief that a combined method can produce superior results can be seen through these studies it may not transfer to highly trained individuals as stimulus requirements and high current maximal strength levels of the athletes may produce different test results. Also, while Cormie et al. (2007) used the squat jump exercise in both groups during intervention and used this same exercise as a testing measure the increase in results could be partially due to a learning effect of the exercise and not solely due to the training intervention.

Kotzamanidis et al. (2005) used a different combined training approach on recreationally trained soccer players consisting of a 12- week intervention program on two training types; strength only or strength and high velocity running combined. The participants trained twice weekly following the same strength programme for back squat, leg curl and step up at increasing loads and decreasing repetitions of eight, six and three. The combined group then followed the resistance training session with four, five and six maximal speed 30m sprints 10 minutes prior to finishing the resistance programme session each time. The groups were pre and post tested on 1RMs of back squat, step up and leg curl. Each group was also tested on jump height in squat jump, counter movement jump and drop jump for force, height and sprint velocity on a 30m sprint. The concluding tests revealed that the combined training influenced positively on all 1RM tests, squat jump, counter movement jump and 30m sprint. The strength only group improved in all 1RM tests. The authors inferred that a combined approach to training had a better training effect and performance outcome on tests than strength alone. These conclusions are in line with other studies (Adams et al., 1992; Haff and Nimphius, 2012) on combined training methods for sport performance requirements, however, when examining the intervention programmes used, the combined group trained 30m sprints during the intervention which similarly to Cormie et al. (2007), could show results associated with the learning effect and repetitions performed regularly of the 30m sprint and not the whole intervention program itself. The participants were recreationally trained soccer players, therefore, it could be the training effect of an increase in volume of training that has resulted in these improvements and not the actual intervention used.

Another considering factor would be the influence of post activation potentiation of the strength training 1RMs on sprint performance as these were carried out directly after resistance training. The counter movement jump scores were significantly improved in the combined group and unlike the repetition of sprinting exercise or learning effect on the sprint test the counter movement jump was not included in the training program. However, as sprinting is maximal speed running it requires the stretch shortening cycle to work continuously throughout the running motion which is required also in the counter movement jump which may have caused the significant improvement for the combined group results (Harrison et al.,2004).

2.5 Jump performance as a performance measure

The use of jump squat as a performance measure for force, velocity and power capacity of an athlete has been validated by Samozino et al. (2008, 2015) with Seitz et al. (2014a) also supporting the use of jump squats for predictors in other sporting variables such as sprinting performance. Seitz et al. (2014b) reported that lower body strength in back squat transfers to improved 20m sprint performance in junior elite rugby league players and is fundamental to improve sprinting times. It was claimed that this training transfer is due to the ability of the individual to produce higher peak ground reaction force with a greater rate of force development during each foot strike when compared to individuals with lower strength levels. In a meta-analysis conducted by Seitz et al. (2014a) training variables and methods were analysed to determine differentiating training exercises and methods for determining sprint improvements. The analysis reported no differentiating factors in testing variables between back squat and jump squat to sprint performance and further suggested that improvement measures in sprint times were greater in studies using combined training approach of heavy and light load exercises. Furthermore, it was suggested that using a combined approach including the use of back squat, jump squat, counter movement jumps and plyometric exercises elicited greatest improvements which underpins the intervention program suggested in the study to be conducted.

2.6 Summary and Rational

While there has been much research on the combined training approach (Adams et al., 1992; Cormie et al., 2007; Haff and Nimphius, 2012; Harris et al., 2000; Kotzamanidis et al., 2005) for better transfer of overall performance across a wide range of skill requirements for sport, the majority of research has been carried out on recreationally trained individuals and on the sport of soccer. Research conducted in this area on highly trained individuals is lacking which could significantly skew results of training adaptations achieved. Research on studies on rugby players have focused on the strength requirements (Appleby et al., 2012; Corcoran and Bird 2009), position specific physiological needs (Duthie et al., 2006; Grant et al., 2003) or running patterns (Duthie et al., 2006; Gabbett et al., 2008) but rarely on the "transfer of training effect" of strength training to on pitch performance or various athletic key performance indicators (Harris et al., 2000). Therefore, examining the force velocity relationship of elite players and how it can be affected with training programmes designed off the basis of improving force and velocity capabilities together, a gap exists in the research available. Force-velocity profiling during training exercises such as squat jump allows for a visual guide to tracking athlete progress over training periods and over a wider range of loads across the force/velocity spectrum in comparison to 1RMs. Using this method for sports that require maximal strength development and high velocity demands in different capacities such as rugby would be of importance for game performance and demands (Roberts et al., 2008; Quarrie et al., 2000). These profiles allow for calculations of theoretical force, velocity and power capacities of athletes, relating requirements on pitch, depending on positional demands of athlete, to training program needs, as 1RM strength tests may not be an accurate indicator or transfer to what is needed of each individual player when the athlete is on pitch (Jovanovic and Flanagan, 2014).

2.7 Research Questions

Can improvements be made to force in a five-week force-velocity training program in sub academy rugby players?

Can improvements be made to velocity in a five-week force-velocity training program in sub academy rugby players?

Can improvements be made to maximal power in a five-week force-velocity training program in sub academy rugby players?

Could a force-velocity approach be superior to a conventional strength program?

Chapter 3. Methodology

3.1 Conceptual Design and Subjects

This research adopted a quantitative method to data collection on jump heights to calculate the variables of theoretical force, velocity and power to assess the impact of a five-week intervention program on jump performance in elite sub academy rugby players. Jump performance is a validated measure of force, velocity and power and also related to sprinting capabilities of field athletes (Samozino et al., 2008, 2015; Seitz et al., 2014b; Young et al., 1995). The first phase of this research incorporated testing of all participants to obtain force, velocity and power measures and create a force-velocity profile for each athlete. Eighteen male sub academy rugby players with minimum one-year weight training experience, age (yr.) (M = 16.94, SD = 0.80), height (cm) (M = 185.91, SD = 10.88), weight (kg) (M = 87.23, SD = 16.81) participated in this study (see table 1). Participants did not report any injuries, health problems or limitations prior to beginning of study. Assessment on jump performance was conducted pre and post intervention using a Just Jump System jump mat, 20kg barbell and weight plates.

3.2 Testing Protocol

Familiarization of squat jump technique and testing protocol was performed in three consecutive sessions in the two weeks prior to initial baseline testing under coach supervision following warm up. The warm up was kept consistent throughout each session from familiarization, intervention and testing period. Participant measurements including weight (kg), height (cm), leg length (cm) in full extension to simulate take off position and initial squat position were recorded. Full extension was measured by instructing the athlete to lay supine on the floor with maximal foot planter flexion, measurement from the top of the right leg greater trochanter to the top of the hallux recorded. Participants were then instructed to squat down to a 90° knee angle position to form the jump take off position to be used during each trial and vertical measurement recorded from right leg greater trochanter to the ground.

This position was visually monitored by the test administrator for each squat jump attempt for reliability and validity.

Participants performed a 10-minute warm up consisting of active stretching, glute activation and potentiating exercises of the squat which were performed prior to every weights session. The contents of this warm up are contained in table 2. Verbal instruction on jump squat technique and testing protocol were communicated. Participants were told to apply force as quickly as possible and jump for maximum height, landing with the same leg position as take-off position. Participants were given five minutes prior to testing to familiarise with setup of test and equipment. The test was conducted with five weight increments applied to the barbell with two attempts given at each weight. If the final jump height recorded exceeded 15cm (Samozino et al., 2008) an additional trial was included with a further weight increment to allow for validity of testing protocol. A rest period of three minutes between increasing loads was given to each participant (Matuszak et al., 2003). Each trial comprised of the participant un-racking the barbell from the squat rack with the barbell across the shoulders, stepping back onto the jump mat and on instruction squatting down to pre-recorded starting height. Following a pause of two seconds, to minimise the participant utilising the stretch shortening cycle, the participant was then signalled to jump. If verbal instruction criteria was not met the data from the jump was not recorded and a repeat of the jump trial allowed following a three-minute rest.

3.3 Data Collection – Baseline Test

The participant's weight (kg), leg length at full extension (cm), leg length at starting squat jump position (cm), weight increments (kg) and jump height (cm) for each trial attempt were input into Microsoft Office 365 Excel (version 1803). Using the validated force-velocity equation method (Samozino et al., 2008) theoretical force (N/kg), velocity (m/s) and power (w/kg) were calculated and a force-velocity profile produced for each participant. The R-value was visually examined to insure correlated results and correct data input.

3.4 Intervention Design

Following testing the participants were randomly assigned to the FVG (*n* = 9) or HTG (*n* = 9). A five-week intervention training program consisting of two 60-minute weights sessions per week were performed. Participants completed normal in season training of two field-based rugby sessions and one match per week during the five-week intervention. The HTG followed a standard strength training program they would usually complete consisting of back squat at high force >85% 1RM of five repetitions and six sets. The FVG performed back squat program of >85% 1RM of five repetitions four sets and further performed back squats at 30-50% of 1RM of five repetitions two sets. Light load sets were monitored to insure players were maximising speed on the concentric portion of the squat. The FVG completed supersets of high load back squats with four counter movement jumps at bodyweight for each set completed. The training programs for each group are displayed in table 2. Program duration was equal in both groups and sets/reps on back squat matched for overall repetitions performed. Both groups trained upper body session as programmed by academy. Following completion of five-week training intervention, each player was re-tested at week six on same exercise, protocol, variables and equipment as pre-testing.

Table 1. Participant characteristics of the Force-Velocity group and Heavy Training group. Values expressed as mean ± standard deviation.

	FVG (*n* = 9)	HTG (*n* = 9)
Age (yr.)	17 ± 0.9	16.9 ± 0.8
Height (cm)	182 ± 12.2	189.8 ± 8.3
Weight (kg)	80.3 ± 19.1	94.3 ± 11.2

Table 2. Intervention programme warm up, exercises, sets and repetitions for FVG and HTG.

Training sessions	Force-Velocity Group	Heavy Training Group
Warm up	Dynamic stretching (ankle, calf, hamstring, quadriceps, hip flexor, back - erector spinae, latissimus dorsi) Glute bridge double/single leg BW squats Walking lunge Single leg Romanian deadlifts	Dynamic stretching (ankle, calf, hamstring, quadriceps, hip flexors, back - erector spinae, latissimus dorsi) Glute bridge double/single leg BW squats Walking lunge Single leg Romanian deadlifts
Back Squat >85% 1RM	5 reps 4 sets	5 reps 6 sets
Counter Movement Jump	4 reps 4 sets	
Back Squat 30-50% 1RM	5 reps 2 sets	

3.5 Data Collection- Post Intervention and Analysis

Results of post- test jump heights were analysed in the same form as baseline testing to produce theoretical force (N/kg), velocity (m/s), power (w/kg) measurements and force- velocity profile of post- test produced for each participant. Mean and standard deviation of baseline and post intervention force (N/kg), velocity (m/s) and power (w/kg) were compared for difference for the FVG and HTG. Percentage change of each of these variables was calculated for each participant within each group with mean and standard deviation of FVG and HTG percentage change compared for significant difference. Pre and post force-velocity profiles of each participant were visually assessed to determine shifts in curve and effect of intervention.

Data was checked for normality using Shapiro Wilk W test in SPSS (version 22). Paired sample t test was used for analysing significant differences between pre and post scores for each group and t-test sampling assuming unequal variance was used to analyse the percentage change of each variable for each group using Microsoft

Office 365 Excel (version 1803). Significance level was set at $p \leq 0.05$. All data was reported as mean and standard deviation (SD).

3.6 Ethical Considerations

All participants and parents were informed of program details and possible risks associated with participation in the study regarding weight training and injury risk. Consent forms were given to all participants over the age of 18 and parental consent for participants under the age of 18 at commencement of study. A medical history questionnaire was completed, and consent form signed by all participants prior to testing (see appendix 3). Data storage of participant details and intervention results were stored through file encryption on a secure encrypted personal laptop with participant number assigned and no name storage used.

Chapter 4. Results

4.1 Descriptive Statistics

Participants individual jump heights and weights were analysed using Morin (2008) force-velocity profile equation (Samozino et al., 2008) to produce theoretical force, velocity and power scores at baseline and post intervention (week 6). Individual participant results for force (figure 1), velocity (figure 2) and power (figure 3) at baseline testing and post intervention (week 6) for participants in both groups are shown below. Mean and standard deviation baseline and post intervention data for all measures are presented in table 3. Both training groups showed similar between group baseline scores with velocity (m/s) (*M* = 1.77, *SD* = 0.09, *M* = 1.90, *SD* = 0.35) and power (w/kg) (*M* = 15.19, *SD* = 1.66, *M* = 15.01, *SD* = 1.41) and small difference in mean force (N/kg) (*M* = 34.39, *SD* = 3.97, *M* = 32.03, *SD* = 2.81).

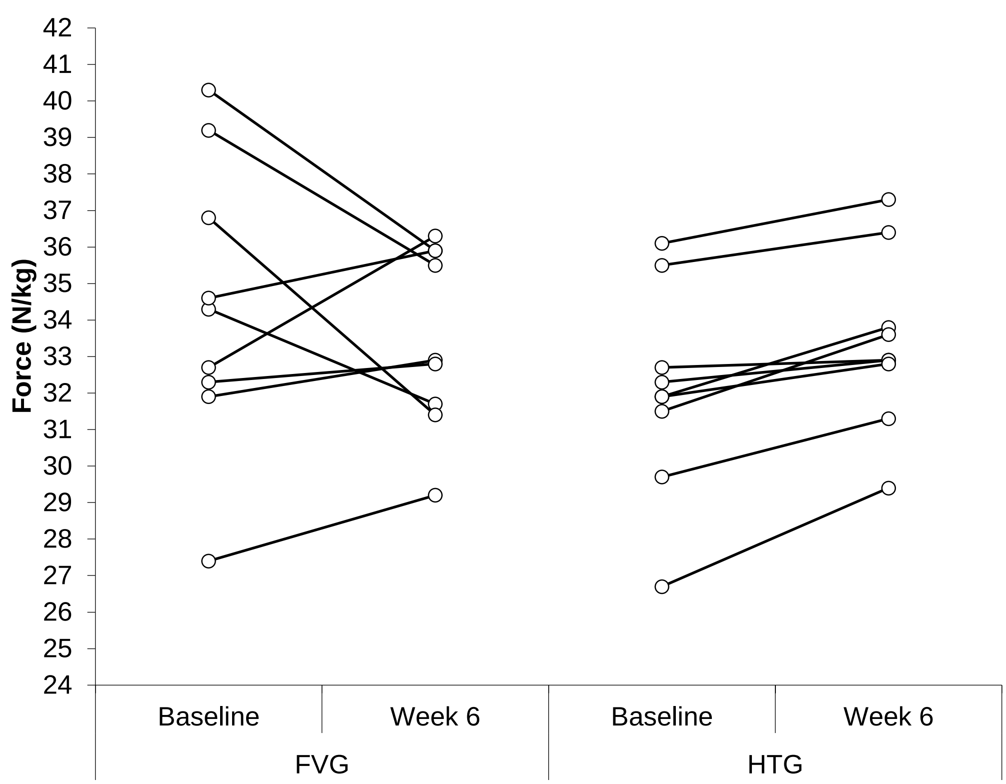

Figure 1*.* Individual participant results of force change pre to post testing following 5-week intervention.

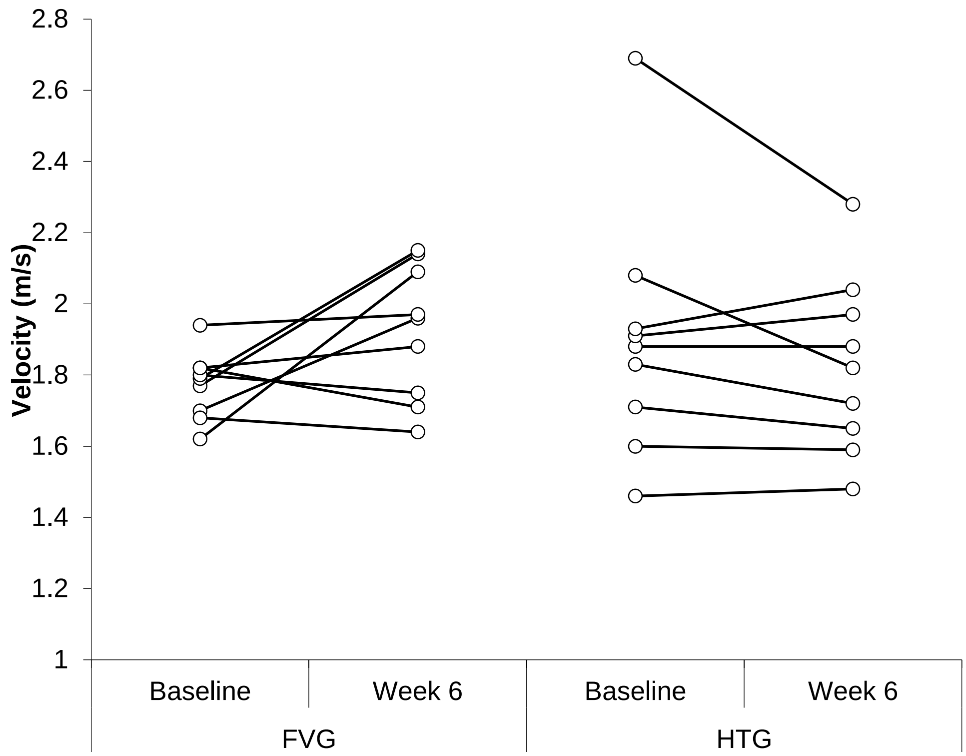

Figure 2. Individual participant results for change in velocity pre to post testing following 5-week intervention.

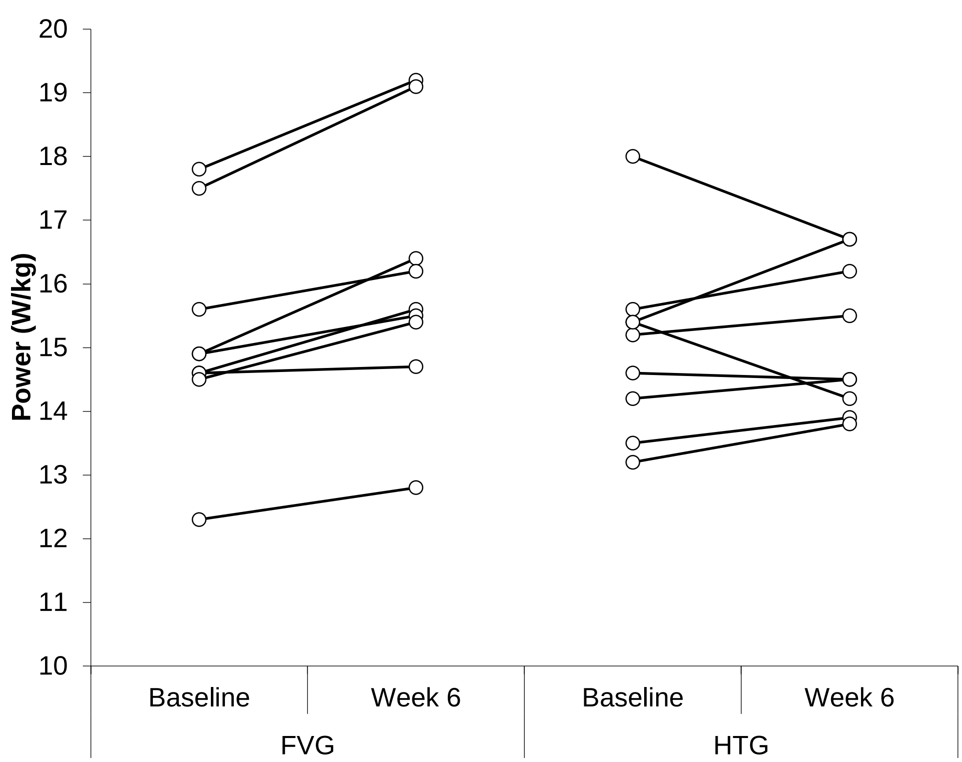

Figure 3. Individual participant results for change in power (w/kg), pre to post testing following 5-week intervention

Table 3. Baseline (pre) and post testing values expressed as mean ± standard deviation produced during squat jump testing using Morin (2008) force-velocity equation.

	Force-Velocity Group (n = 9)		Heavy Training Group (n = 9)	
	Pre	Post	Pre	Post
Force (N/kg)	34.39 ± 3.97	33.51 ± 2.51	32.03 ± 2.81	33.38 ± 2.39
Velocity (m/s)	1.77 ± 0.09	1.92 ± 0.19	1.90 ± 0.35	1.83 ± 0.25
Power (W/kg)	15.19 ±1.66	16.10 ± 2.02	15.01 ± 1.41	15.11 ± 1.18

4.2 Inferential Statistics

Statistical values for difference in baseline to post intervention was carried out using a paired two sample for means t-Test (table 4). The HTG demonstrated significant difference in mean force (t = -5.07, p = 0.0009) with no significant difference in mean velocity (t = 1.33, p = 0.22) and no significant difference in power (t = -0.35, p = 0.73). The FVG showed significant difference in power (t = -5.35, p = 0.0007) while no significant difference was found in force (t = 0.83, p = 0.83) or velocity (t = -2.08, p = 0.07).

Table 4. FVG and HTG training intervention effect pre to post intervention p values and t statistic for each measured variable using paired T-test for means.

	Force-Velocity Group (n = 9)			Heavy Training Group (n = 9)		
	Force	Velocity	Power	Force	Velocity	Power
P value	0.4324	0.0707	0.0007	0.0009	0.2205	0.7337
T Stat	0.83	-2.08	-5.35	-5.07	1.33	-0.35

4.3 Percentage Change of Groups

Percentage change from pre to post scores were calculated with standard deviation for both groups and displayed in table 5. The FVG percentage changes in force (-2.65%, *SD* = 9.49%), velocity (6.97%, *SD* = 10.55%) and power (5.47%, *SD* = 2.68%) were analysed in relation to the HTG force (4.11%, *SD* = 2.66), velocity

(3.68%, *SD* = 7.91) and power (0.64%, *SD* = 5.46) for statistical difference. Statistical analysis using two-sample assuming unequal variance t- Test of between groups percentage change for each variable is show in table 6. No significant differences were observed between groups.

Table 5. Percent change (mean ± SD) produced during 5-week intervention in two separate groups (FVG and HTG).

	Force-Velocity Group %	Heavy Training Group %
Force (N/kg)	-2.65 ± 9.49	4.11 ± 2.66
Velocity (m/s)	6.97 ± 10.55	3.68 ± 7.91
Power (W/kg)	5.47 ± 2.68	0.64 ± 5.46

Table 6. Between group percentage difference significance of each variable (p value, t stat).

	FVG versus HTG% change		
	Force	Velocity	Power
P value	0.1409	0.0506	0.0703
T Stat	-1.63	2.14	2.00

4.4 Force-Velocity Profile

The following figures are representative of the force-velocity profiles obtained for each group at baseline testing and post intervention testing. Force-Velocity profiles of participants were visually assessed to view changes to the force- velocity profiles of the athlete at each point on the curve. The profiles also show optimal push off profiles for each athlete at 30° and 90° from ground simulating running push off and vertical jump push off respectively. The effect of the five-week training intervention on a participant in the combined load group is shown in figure 4. The resulting profile post intervention shows the profile has shifted right and lies on the optimal line for

90° push of force-velocity production. Both pre-intervention profiles show participants with equal baseline force and marginally different velocity (0.55% difference) with second profile showing results post intervention and the effects on the force-velocity profiles in relation to optimal profiles. Individual baseline and post intervention profiles for each participant are contained (see appendix 1).

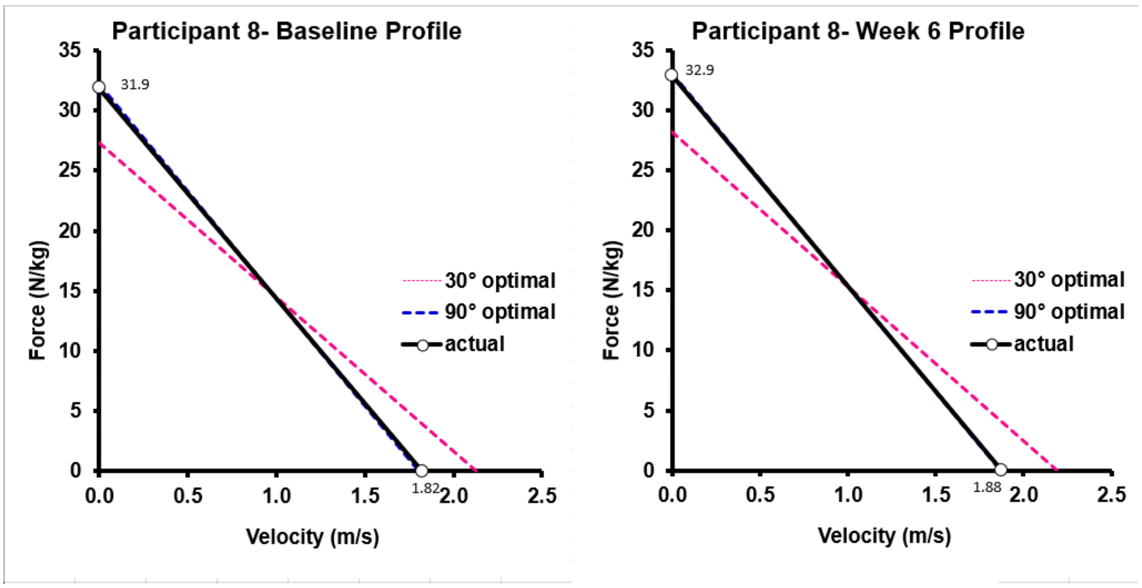

Figure 4. Force-Velocity profile baseline and post test results for participant in combined load group. Blue dash line showing 90-degree optimal profile, pink dash line showing 30-degree optimal profile.

Figure 5 displays pre and post intervention profiles of participant for the heavy load group also visually showing both 30 and 90-degree optimal profiles in relation to the participants actual profile. The post intervention profile shows the shift in the force side of the curve upwards and a decrease in the velocity side creating a steeper profile achieved through a five-week heavy load training program.

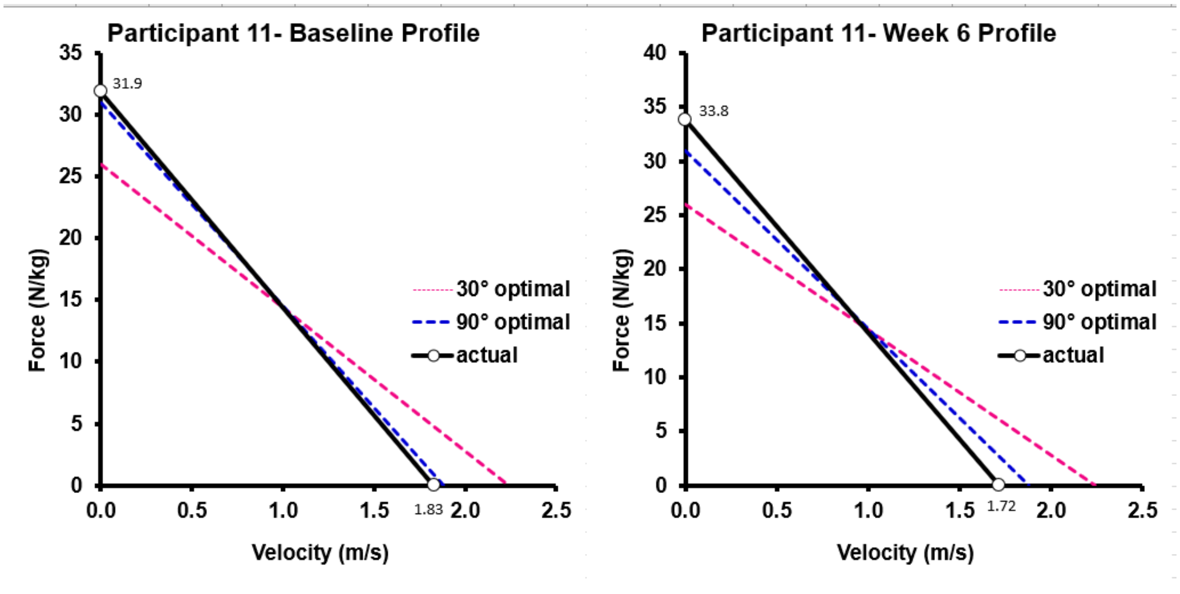

Figure 5. Force-Velocity profile baseline and post test results for participant in heavy load group. Blue dash line showing 90-degree optimal profile, pink dash line showing 30-degree optimal profile.

Chapter 5. Discussion

5.1 Introduction

To add to the body of research in the area of combined load training for performance by Cormie et al. (2007), Harris et al. (2000) and Kotzamanidis et al. (2005) the aim of this study was to investigate if force, velocity and power could be improved in a five-week training intervention using squat jump testing on elite sub academy rugby players. The results of post-test data concluded that the FVG significantly improved their power (w/kg) while the HTG significantly improved force (N/kg). All other variables did not find significant changes during the intervention. However, the FVG showed a trend towards improvement for velocity (p = 0.07) which could assist further studies in this area. The percentage change of these variables was measured for both groups pre and post-test with these percentages compared for significance. No significant difference was observed between group changes for any of the variables. From the results it is not clear if a combined force-velocity training load program is superior to a heavy training load only program. However, as the FVG showed significant improvement in power (force * velocity) if the goal of training was power production alone then the combined force-velocity training load would be deemed superior. Similarly, if force production was the main goal of training the HTG program would be more suitable.

5.2 Force

The FVG showed an insignificant reduction in force produced from baseline testing while the HTG increased force significantly similarly to results found by Argus et al. (2012) in which jump test results showed improvements in peak force output in the strength power group. Due to the training program, the HTG would have increased their force capabilities by training exclusively at the higher end of the force velocity curve. The decrease in force shown in the FVG could have been due to the reduction in sets lifted at high load (six compared to four). The training volume for high load was not matched between groups due to an attempt to keep overall training volume equal and therefore the high load volume for the FVG may not have been sufficient to maintain or increase force production over five weeks in comparison to the HTG training volume. Therefore, the greater intensity of high volume work by the HTG and lower volume intensity by the FVG may have affected the results obtained. This was similarly seen in Argus et al. (2012) where the strength power group had greater intensity over the speed power group in strength exercises due to the load and volume this group lifted over the course of the study.

In contrast to the FVG results Tuomi et al. (2004) found that performance adaptations in a combined training intervention have a larger effect on the higher force rather than lower force measures, however in the present study the higher force was negatively affected by the combined force-velocity training program. Again, this could be due to the volume of training load as stated above and an inadequate exposure to heavy loads.

5.3 Velocity

Neither the FVG or the HTG showed significant improvements in velocity from pre to post testing. While the FVG trained using high velocity exercises such as counter movement jumps and 30% 1RM back squats there was no significant improvements measured. However, the trend for improvement in velocity was shown in the FVG results from baseline which may have been a significant difference if the training intervention was longer in duration as McBride et al. (2002) used an eight-week intervention and found significant improvements in velocity for loads ranging from 30-80% of 1RM. De Villarreal et al. (2009) and Toumi et al. (2004) also suggested that to achieve maximal improvements in high velocity activities such as bodyweight and low weight training a longer training period or greater volume may be required.

The volume of light load exercises used could have affected the results also as De Villarreal et al. (2009) stated that for optimal performance improvement in this area, programs should include 50 contacts twice weekly. This was not met in the current study (32 contacts). Therefore, it is possible that the current training volume for adaptations in the velocity side of the force velocity curve may not have been adequate to elicit significant improvements. In contrast to Moss et al. (1997) findings the HTG did not increase velocity which occurred in the authors results indicating that training with near maximal strength loads improved velocity capabilities along the force velocity curve. However, Moss et al. (1997) study was conducted on elbow flexors which may have been attributed to the lack of training of this muscle prior to intervention in untrained participants, therefore, results could have been due to initial gains unlike this current study were participants were already familiar with the squat exercise and loads with a minimum one-year training. The FVG showed a trend towards improvement for velocity which could assist further studies in this area. If participant numbers were larger this may have resulted in a significant change being recorded along with duration and contacts per week criteria met.

5.4 Power

The FVG showed significant improvements in power from baseline to post test. This contrasts with research suggesting combined training can compromise power development due to the differing stimulus (Baker et al., 2001; Kraemer et al., 1995) and further contradicts the study by Tricoli et al. (2005) who found heavy load weightlifting increases power output over combined squat and plyometric training. However, it similarly reflects Cormie et al. (2007) who found combined load training to improve power at a range of loads in comparison to strength only training.

This could have been due to the training program itself not being of a high enough volume to cause a negative effect on power. Another suggestion is the exercises used during the intervention being of same movement patterns for squat heavy and light load and counter movement jump in contrast to other methods that have used squat and sprinting for combined training, thus engaging different muscle contractions and use (Kotzamanidis et al., 2005). Training history is also a factor in the power increase as the athletes would have been typically strength trained, introducing new stimulus such as the counter movement jump and 30% 1RM back squat over the five-week intervention could be result of initial gains which resulted in an improved power output. If this study was conducted over a longer training period and testing carried out mid intervention and post it may produce different results in relation to power which has been seen in other research stated above.

5.5 Conclusion

The findings from this study suggest that a combined force-velocity training program can increase maximal power (w/kg) over a five-week period in elite sub academy rugby players and may be more beneficial for increasing maximal power compared to a heavy load training program. It also may be possible to increase velocity capacities during this type of program if criteria such as program duration and exercise volume are adjusted. Force capacities alone are increased by training at the high force end of the force-velocity curve through a heavy load training program.

5.6 Limitations

The sample size of the study consisted of 18 participants split evenly into the two groups. The sample size tested may not have been large enough to get a fully accurate representation of the effects of the training program. Also considering research published around plyometric and velocity training (De Villarreal et al., 2009; McBride et al., 2002; Toumi et al., 2004) the length of the intervention (five weeks) may not have been long enough to elicit these changes. Future research should attempt to monitor change over a longer phase for more in-depth comparison of programming. The current study used only the squat exercise focusing on lower body outcome on the force-velocity curve through training therefore there is limited ability to determine differences in training programs for sport performance. Further studies should look to include upper body exercise such as bench press to study the effects of combined load training in conjunction with lower body combined load training for overall physical performance change.

5.7 Practical Applications

Individual weight training programs for rugby players need to account for position specific gains and requirements. The use of profiling athletes force-velocity capacities allows for a visual representation on progress and allows the coach to adjust programming individually for the position specific requirements of athletes. The demands of each position are vastly different to one another on field with some requiring high strength levels, high power output or high velocity capabilities. Profiling athletes allows for coaches to address decrements in force-velocity outputs and search for areas of improvement through minor changes to training type to suit individual demands of the player. Velocity adaptations may be important for backs players and the introduction of exercises along the velocity end of the curve may help in performance. Introducing two sets of light load 30-50% 1RM squat with countermovement jumps (50 contacts twice weekly) to a heavy load program may prove beneficial. Similarly forwards who have reached near maximum strength capacities may be able to increase velocity and therefore power output by including a combined load approach to training. A combined load approach to training may be of interest to athletes competing in sports where power (w/kg) is vital to performance over other variables.

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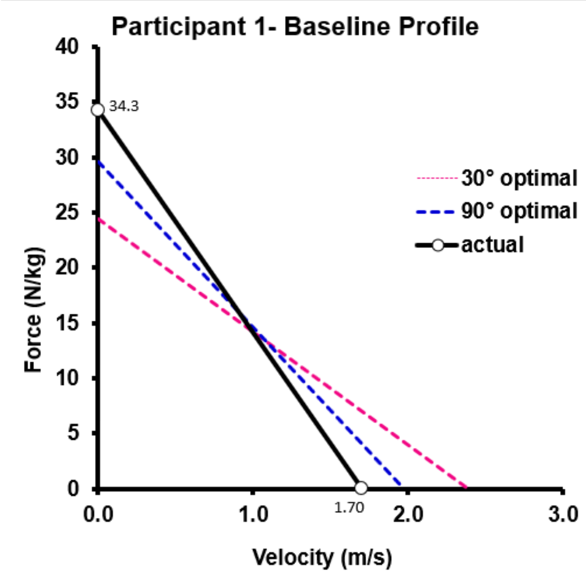
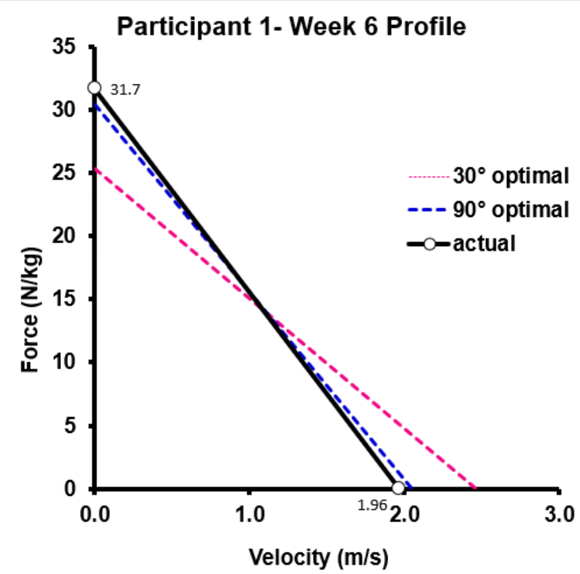
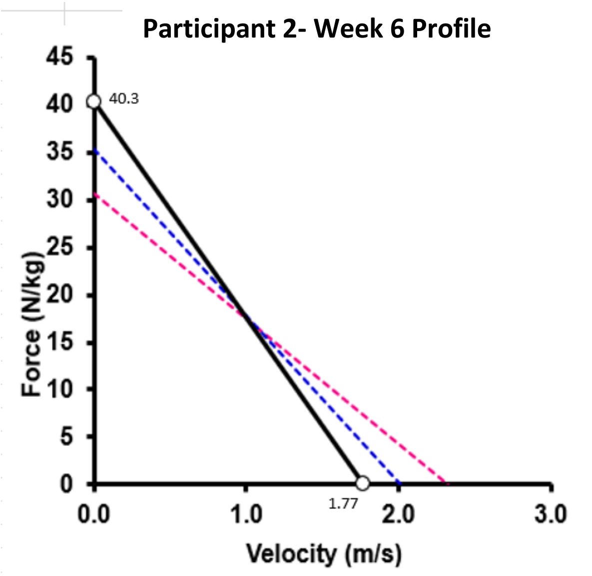
Appendix

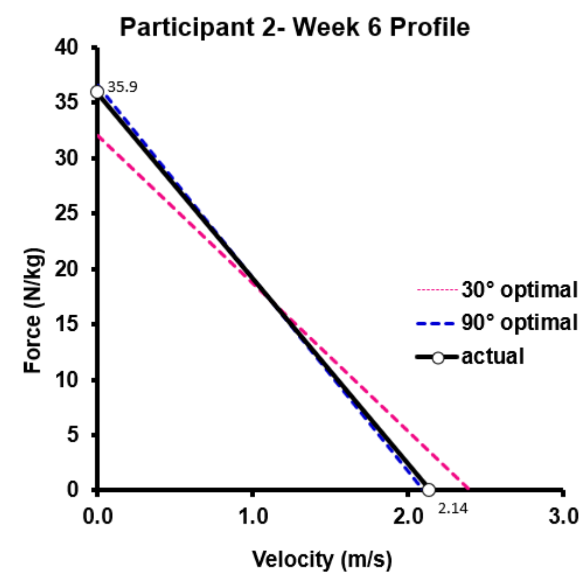
Appendix 1. Force-Velocity Profiles

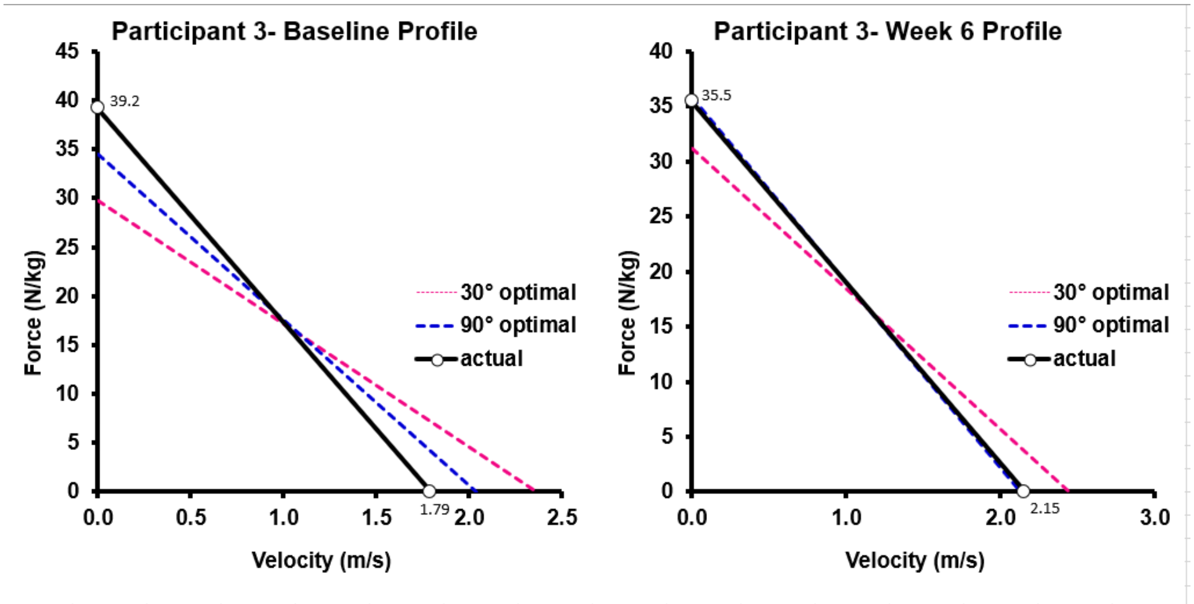
FVG – Participants 1-9 HTG – Participants 10-18

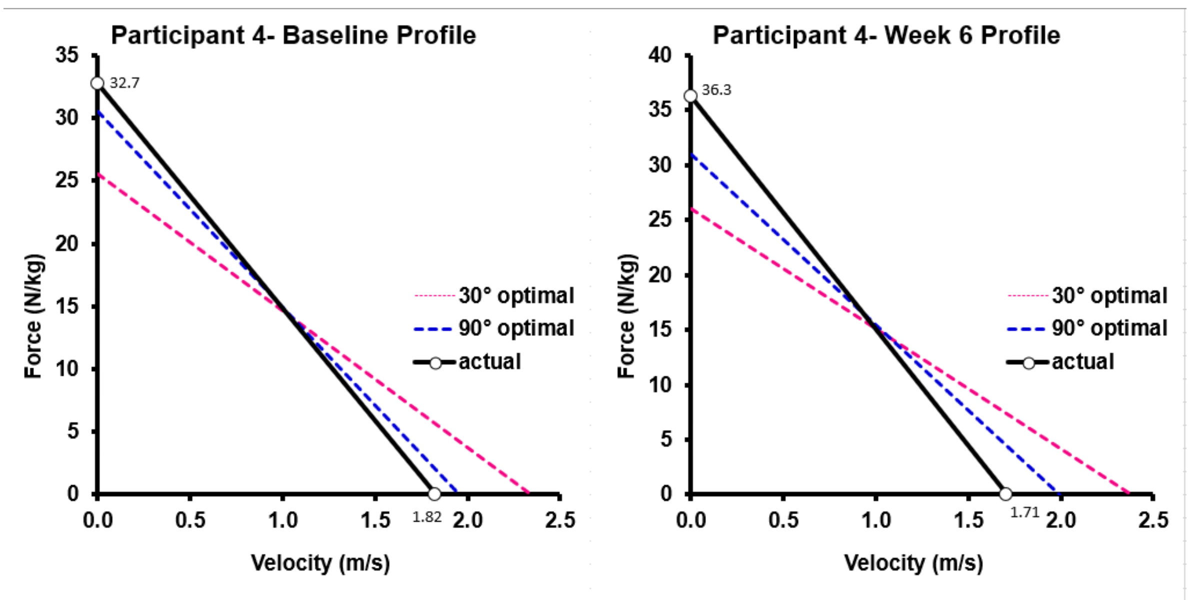


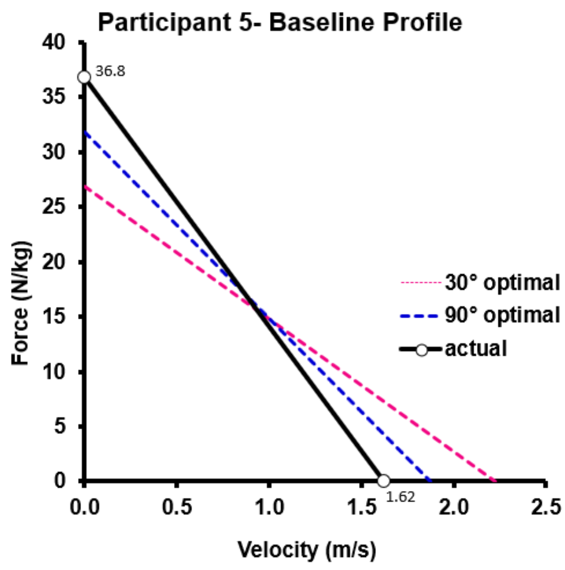


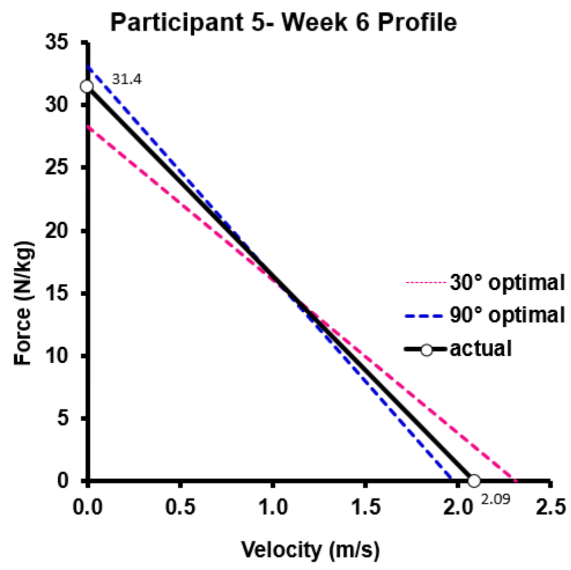


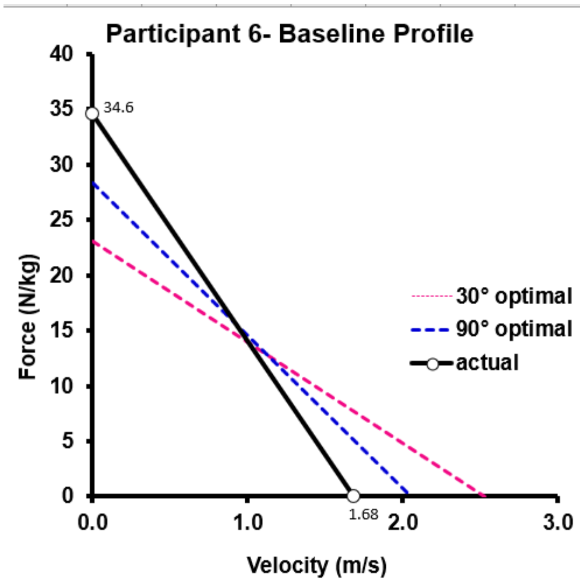


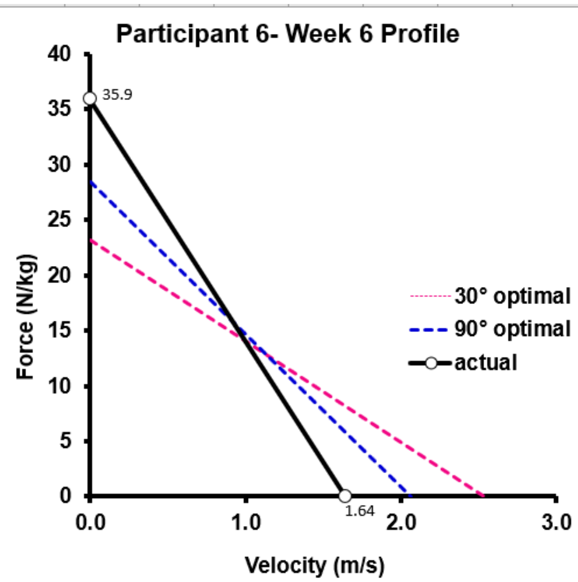

Participant 3- Baseline Profile
Force (N/kg)
Velocity (m/s)
39.2
1.79
30° optimal
90° optimal
actual
Participant 3- Week 6 Profile
Force (N/kg)
Velocity (m/s)
35.5
2.15
30° optimal
90° optimal
actual

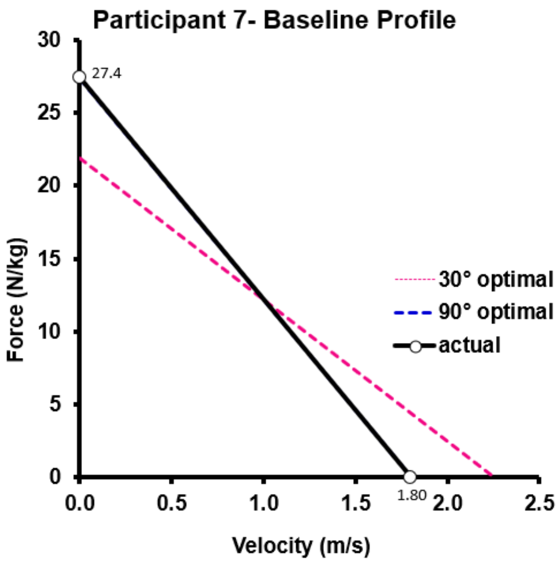

Participant 4- Baseline Profile
Force (N/kg)
Velocity (m/s)
32.7
1.82
30° optimal
90° optimal
actual
Participant 4- Week 6 Profile
Force (N/kg)
Velocity (m/s)
36.3
1.71
30° optimal
90° optimal
actual

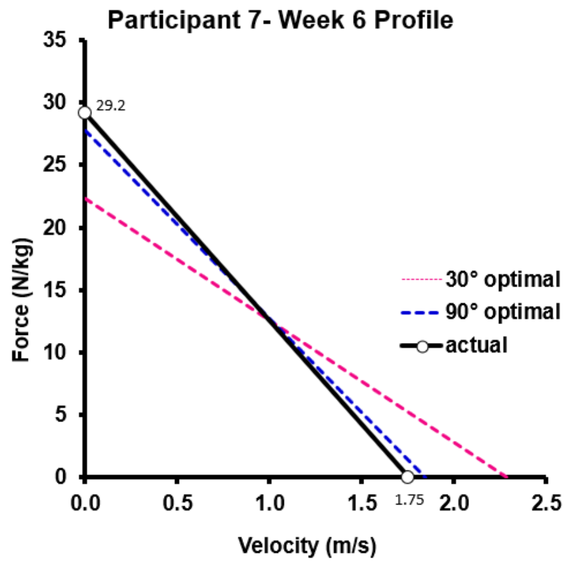

Participant 5- Baseline Profile
36.8
1.62
30° optimal
90° optimal
actual
Force (N/kg)
Velocity (m/s)

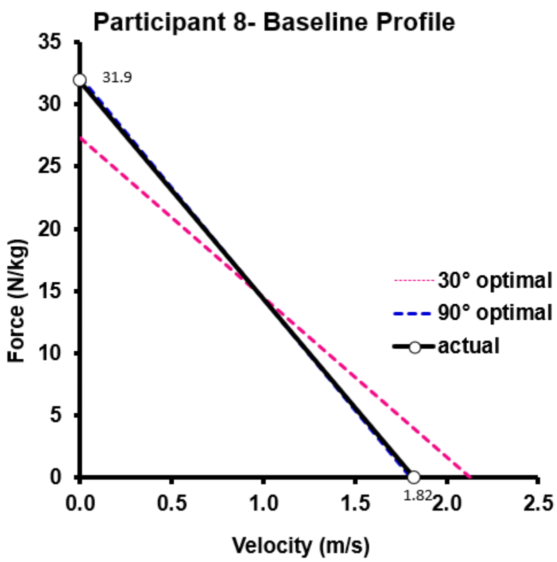

Participant 5- Week 6 Profile
31.4
2.09
30° optimal
90° optimal
actual
Force (N/kg)
Velocity (m/s)

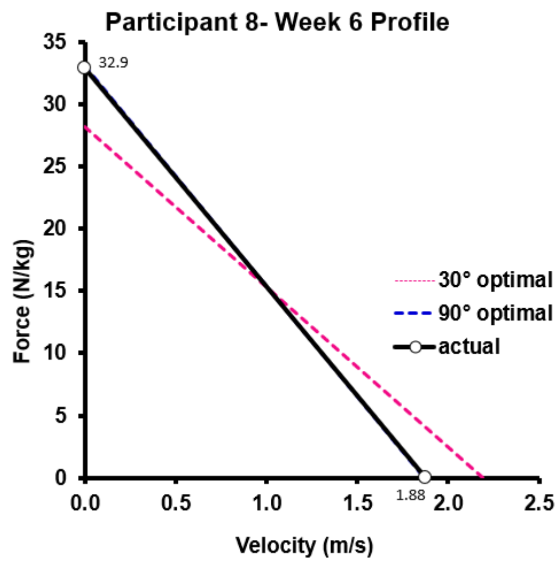

Participant 6- Baseline Profile
34.6
1.68
30° optimal
90° optimal
actual
Force (N/kg)
Velocity (m/s)

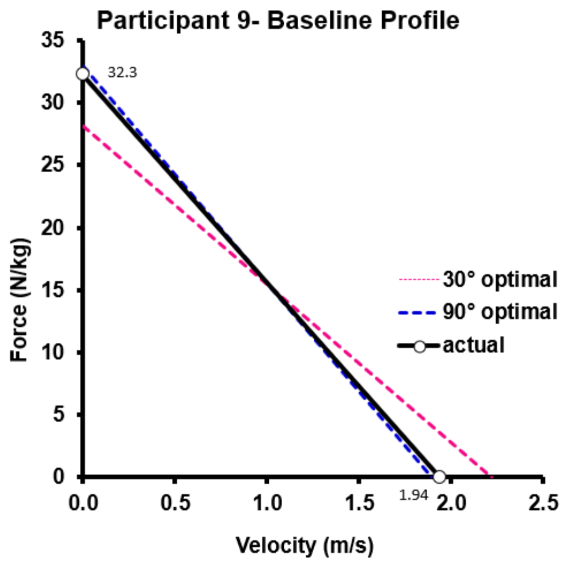

Participant 6- Week 6 Profile
35.9
1.64
30° optimal
90° optimal
actual
Force (N/kg)
Velocity (m/s)

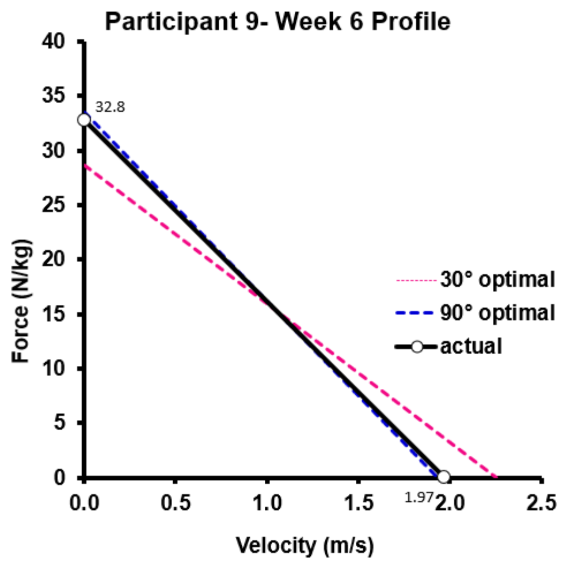

Participant 7- Baseline Profile
Force (N/kg)
Velocity (m/s)
27.4
1.80
30° optimal
90° optimal
actual

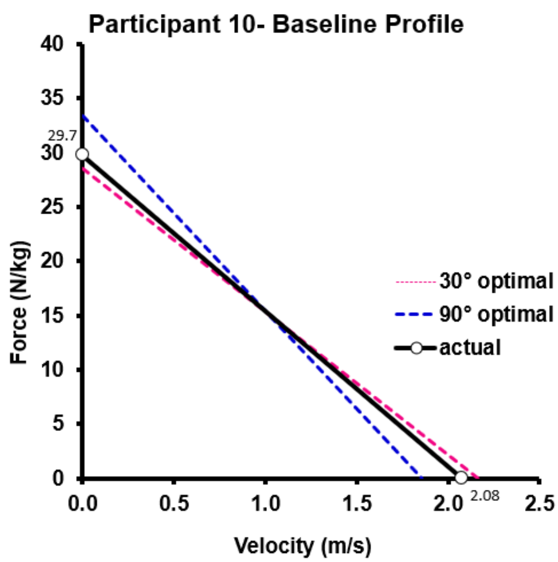

Participant 7- Week 6 Profile
Force (N/kg)
Velocity (m/s)
29.2
1.75
30° optimal
90° optimal
actual

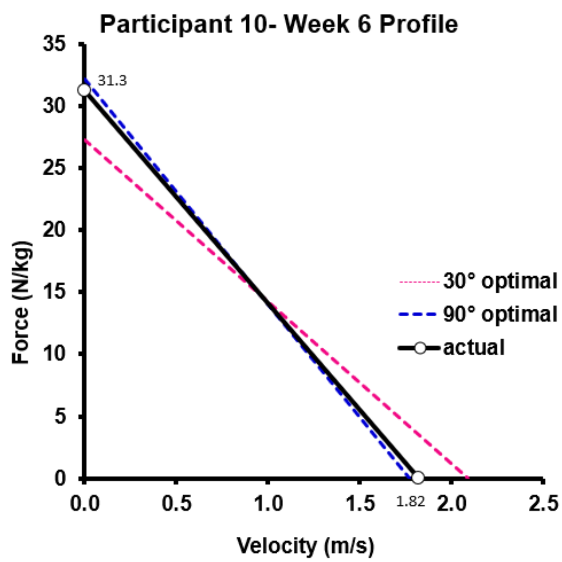

Participant 8- Baseline Profile
Force (N/kg)
Velocity (m/s)
31.9
1.82
30° optimal
90° optimal
actual

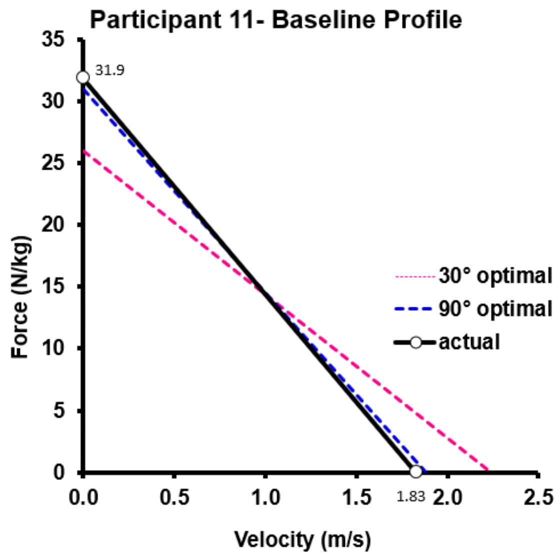

Participant 8- Week 6 Profile
Force (N/kg)
Velocity (m/s)
32.9
1.88
30° optimal
90° optimal
actual

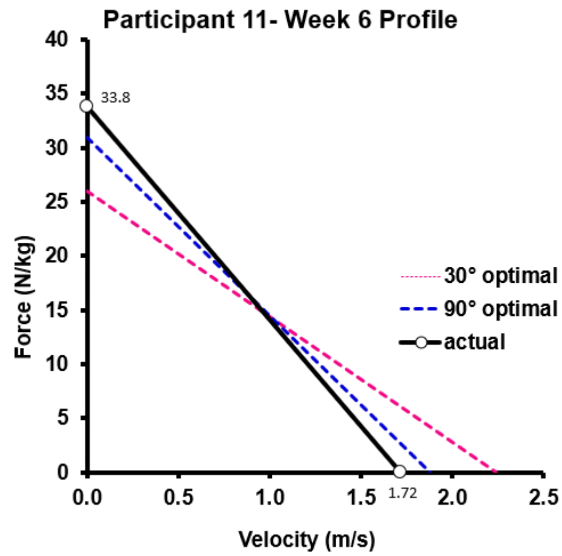

Participant 9- Baseline Profile
Force (N/kg)
Velocity (m/s)
32.3
1.94
30° optimal
90° optimal
actual

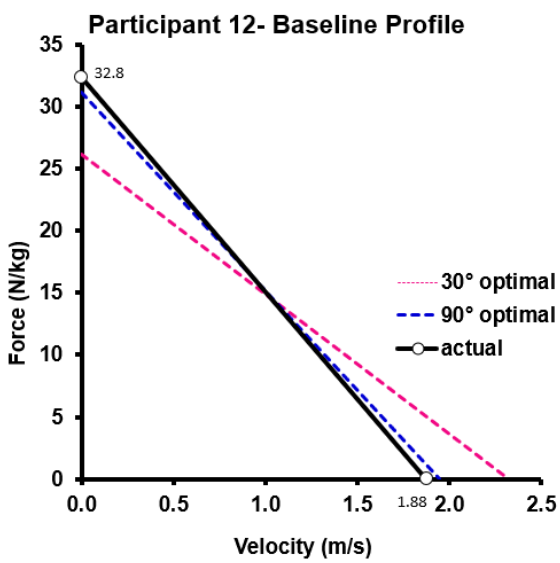

Participant 9- Week 6 Profile
Force (N/kg)
Velocity (m/s)
32.8
1.97
30° optimal
90° optimal
actual

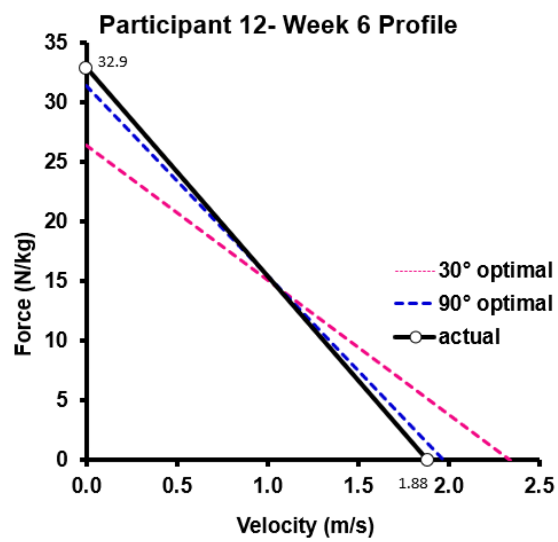

Participant 10- Baseline Profile
Force (N/kg)
Velocity (m/s)
29.7
2.08
30° optimal
90° optimal
actual

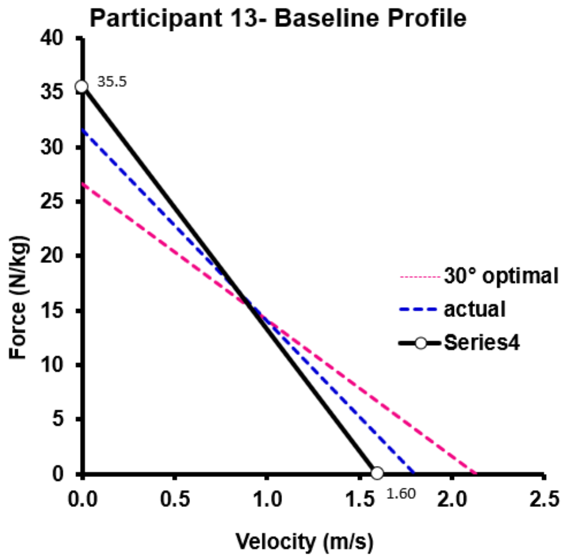

Participant 10- Week 6 Profile
Force (N/kg)
Velocity (m/s)
31.3
1.82
30° optimal
90° optimal
actual

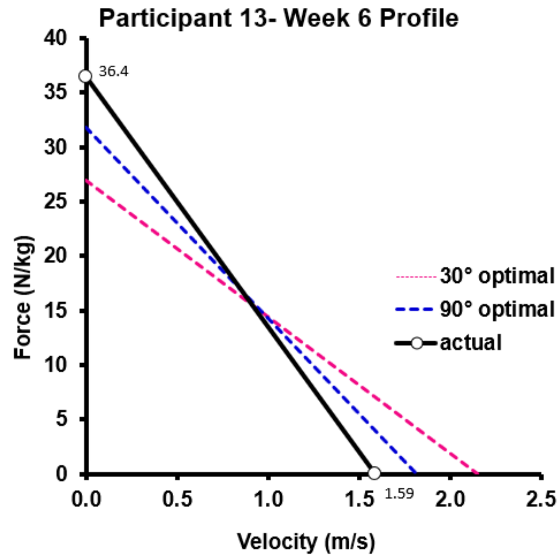

Participant 11- Baseline Profile
Force (N/kg)
Velocity (m/s)
31.9
1.83
30° optimal
90° optimal
actual

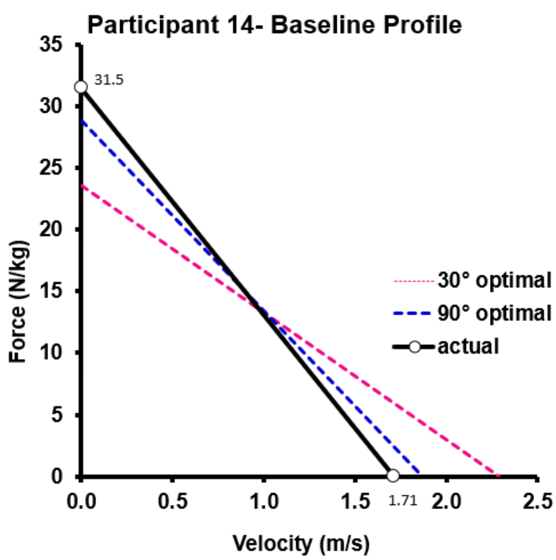

Participant 11- Week 6 Profile
Force (N/kg)
Velocity (m/s)
33.8
1.72
30° optimal
90° optimal
actual

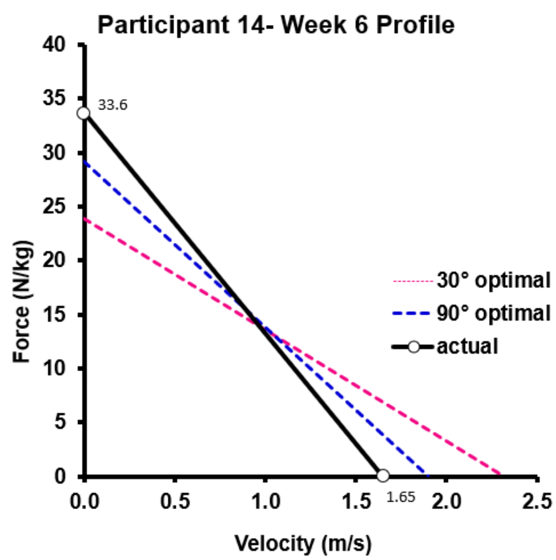

Participant 12- Baseline Profile
Force (N/kg)
Velocity (m/s)
32.8
1.88
30° optimal
90° optimal
actual

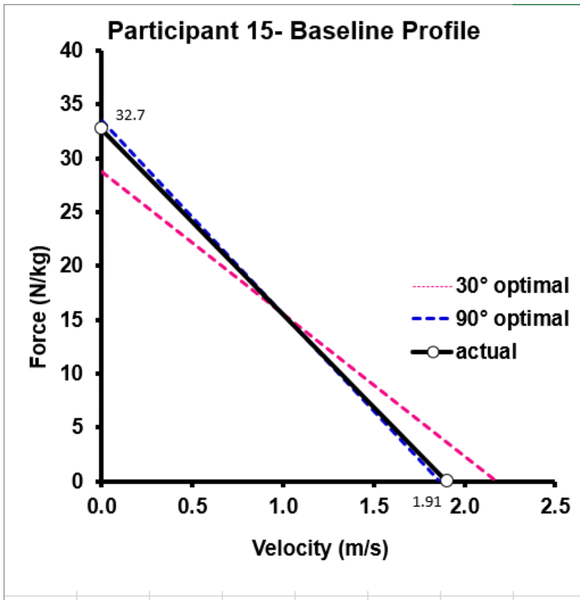

Participant 12- Week 6 Profile
Force (N/kg)
Velocity (m/s)
32.9
1.88
30° optimal
90° optimal
actual

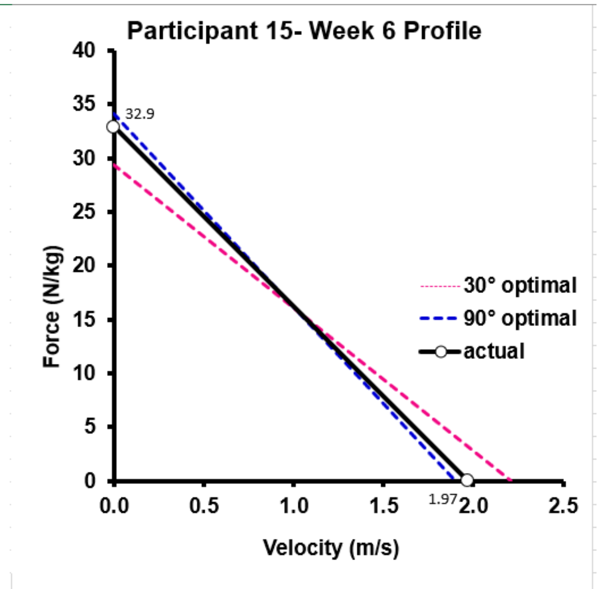

Participant 13- Baseline Profile
Force (N/kg)
Velocity (m/s)
35.5
1.60
30° optimal
actual
Series4

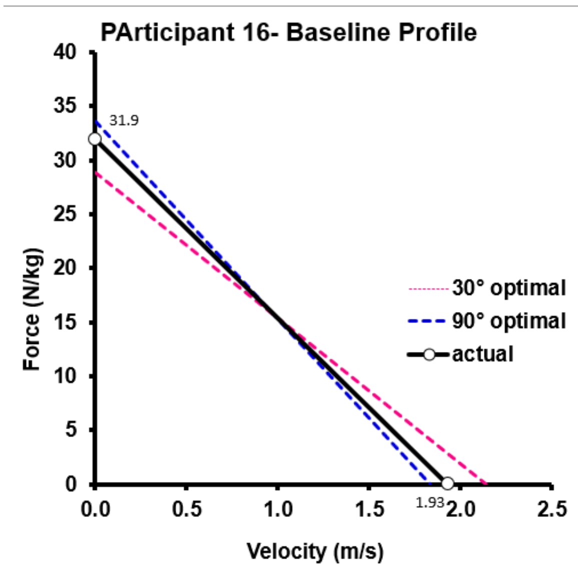

Participant 13- Week 6 Profile
Force (N/kg)
Velocity (m/s)
36.4
1.59
30° optimal
90° optimal
actual

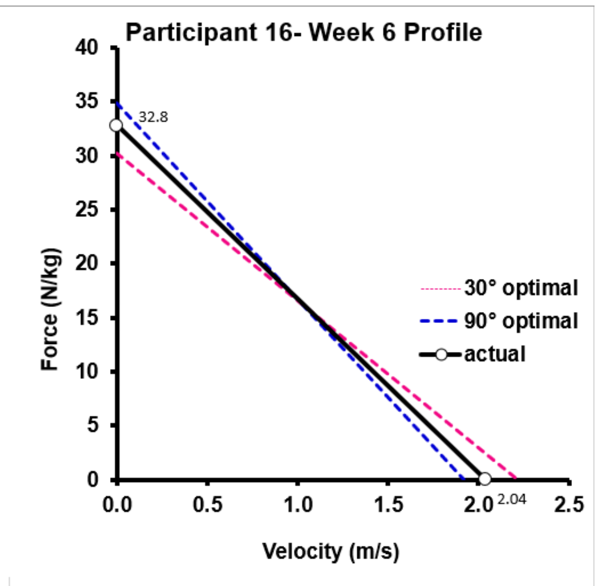

Participant 14- Baseline Profile
Force (N/kg)
Velocity (m/s)
31.5
1.71
30° optimal
90° optimal
actual

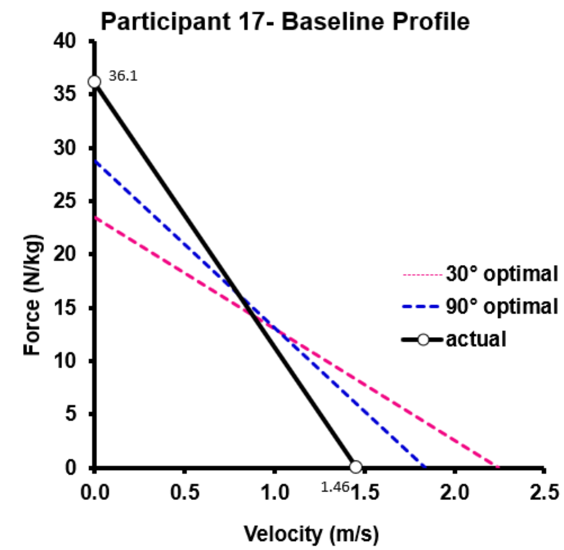

Participant 14- Week 6 Profile
Force (N/kg)
Velocity (m/s)
33.6
1.65
30° optimal
90° optimal
actual

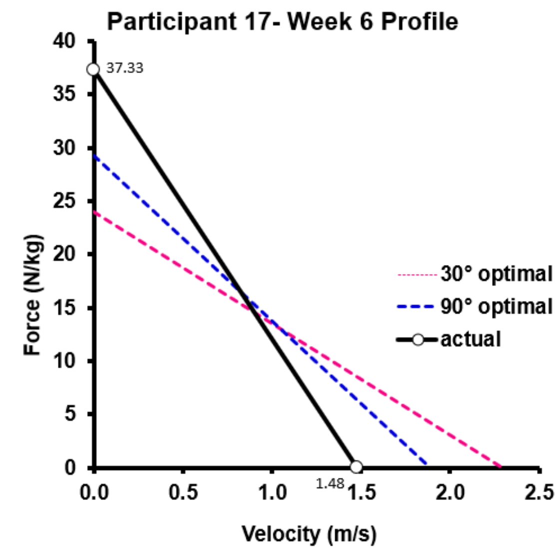

Participant 15- Baseline Profile
Force (N/kg)
Velocity (m/s)
32.7
1.91
30° optimal
90° optimal
actual

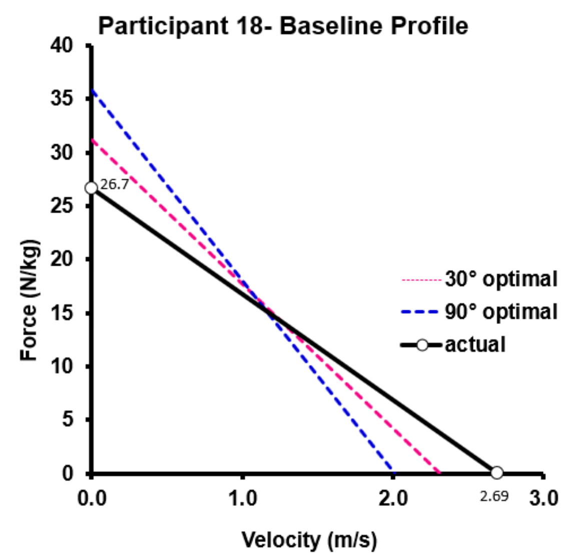

Participant 15- Week 6 Profile
Force (N/kg)
Velocity (m/s)
32.9
1.97
30° optimal
90° optimal
actual

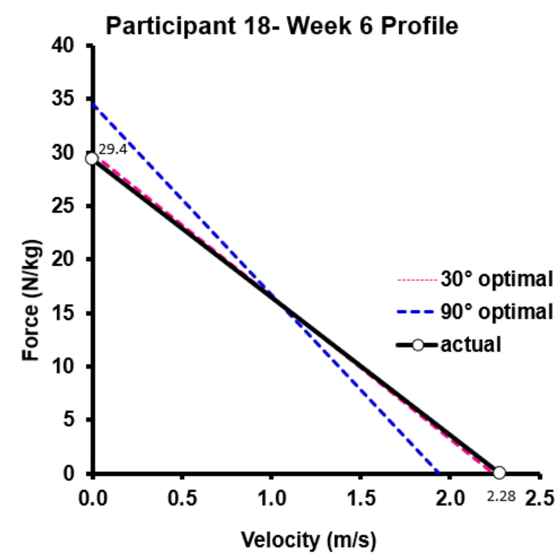

PArticipant 16- Baseline Profile
Force (N/kg)
Velocity (m/s)
31.9
1.93
30° optimal
90° optimal
actual


Participant 16- Week 6 Profile
Force (N/kg)
Velocity (m/s)
32.8
2.04
30° optimal
90° optimal
actual


Participant 17- Baseline Profile
Force (N/kg)
Velocity (m/s)
36.1
1.46
30° optimal
90° optimal
actual
0 5 10 15 20 25 30 35 40
0.0 0.5 1.0 1.5 2.0 2.5


Participant 17- Week 6 Profile
Force (N/kg)
Velocity (m/s)
37.33
1.48
30° optimal
90° optimal
actual
0 5 10 15 20 25 30 35 40
0.0 0.5 1.0 1.5 2.0 2.5


Participant 18- Baseline Profile
Force (N/kg)
Velocity (m/s)
26.7
2.69
30° optimal
90° optimal
actual
0 5 10 15 20 25 30 35 40
0.0 1.0 2.0 3.0


Participant 18- Week 6 Profile
Force (N/kg)
Velocity (m/s)
29.4
2.28
30° optimal
90° optimal
actual
0 5 10 15 20 25 30 35 40
0.0 0.5 1.0 1.5 2.0 2.5

Appendix 2. Clearance Form

Clearance Form

Approval has been granted for the methodology outlined by________________________(student) and clearance has now been given for the project to proceed.

Signed:…………………………………………………………………….(Advisor)

Student's signature

………………………………………………

Date…………………………………….

Appendix 3. Medical and Consent Form

Study Consent & Questionnaire

Name:
Date of Birth:
Age:

Contact Details.

Address:
Phone No. / Mobile No:
Parent/Guardian Name:
Parent/Guardian Mobile No:

The following questionnaire is confirming your consent to participate in this study and to determine your fitness and wellbeing to undertake the physical requirements.

Your personal details will be kept confidential, and the test result figures will be made available to you and stored electronically, accessible only the individual administering this study.

ILLNESS

Are you currently suffering from any type of illness (or have you in the previous 4 weeks)?

[ ] NO [ ] YES

If yes, please provide details……………………..……………………………………………...

Do you have any ongoing medical conditions?

[ ] NO [ ] YES

If yes, please provide details……………………..……………………………………………...

MEDICATION

Are you currently taking any medications? [ ] NO [ ] YES

If yes, please provide details:……………………………………………………………… ……

Have you taken any form of medication over the last two weeks? [ ] NO [ ] YES

If yes, provide details:…………………………………………………………………………

INJURY

Do you currently have any injuries? [ ] NO [ ] YES

If yes, please provide details (e.g., type, severity):..………………………...……………… …

Have you had any minor injuries in the last four weeks? [ ] NO [ ] YES

If yes, please provide details..………………………………………………………………

Have you had any serious injuries in the last 6 months? [ ] NO [ ] YES

If yes, please provide details..……………………………………………………………

Fitness

Do you have any mobility issues/pain in lower body exercise? [ ] NO [ ] YES

If yes, please provide details..………………………………………………………………

Evaluate your last week of training. [ ] EASY [ ] MEDIUM [ ] INTENSE

How fatigued do you feel today? (0 = not at all, 10 = extremely) ………………

List any supplements you are currently taking

Any other information of relevance?

DECLARATION BY Athlete
I have been informed by the tester of the nature and effect of the testing procedure(s) to be administered and I am giving my consent freely and voluntarily. I confirm I am in good health with no illness or condition affecting my capacity to perform exercise to a maximal level of intensity

Signature of athlete……………………………………………………………..**Date**……………

Signature of parent (if athlete is under 18) ………………………………….. **Date**……………

DECLARATION BY Tester
I have informed the athlete of the nature and effect of the testing procedure(s) to be administered and the athletes' consent has been given freely and voluntarily.

Signature of Tester………………………………………. **Date**…………..