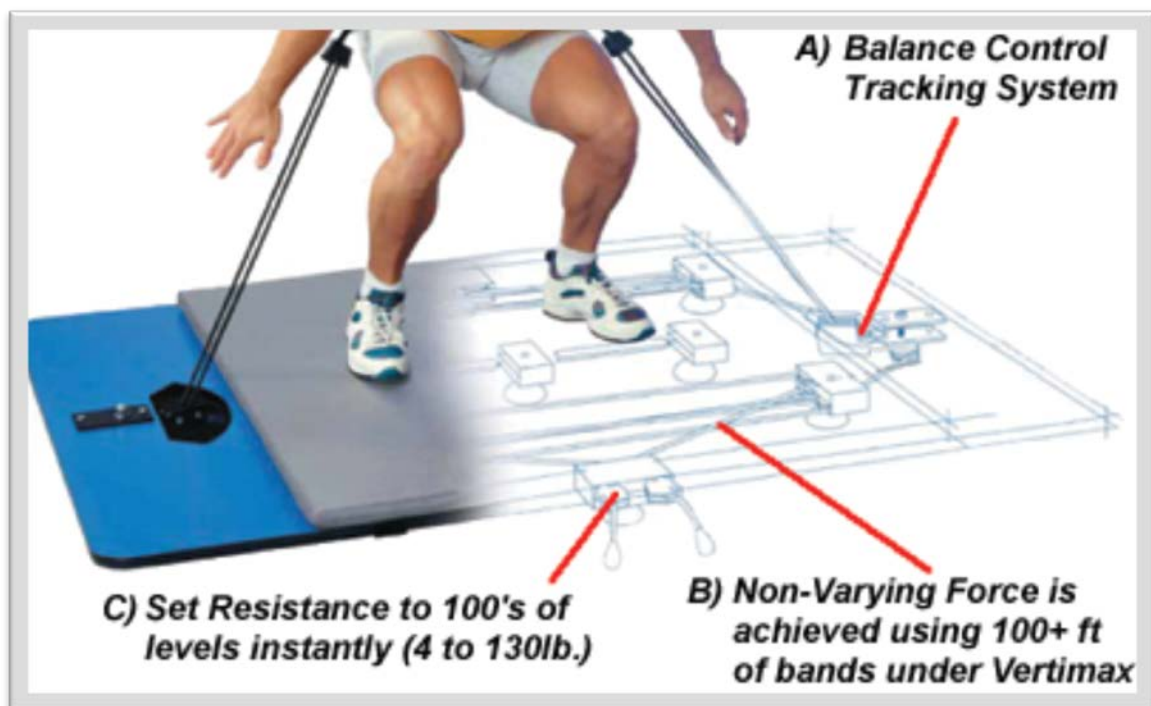


CHAPTER 3



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The effects of a combined resisted jump training and rugby conditioning program on selected physical, motor ability and anthropometric components of rugby players

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Title:

The effects of a combined resisted jump training and rugby-conditioning program on selected physical, motor ability and anthropometric components of rugby players.

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ABSTRACT

The purpose of this investigation was to examine the effects of a 4-week combined rugby-conditioning and resisted jump training program compared to a combined rugby-conditioning and normal jump training program on selected physical, motor ability and anthropometric components of university-level rugby players. Thirty university-level rugby players (19.60 ± 0.79 years) from the first and second u/19 and u/21 rugby teams were randomly divided into two groups of fifteen players each. Twenty-nine direct and indirect anthropometric measurements were taken and the players performed a battery of 8 physical and motor ability tests before and after a microcycle (4-week) combined rugby-conditioning and resisted jump training (experimental group) and a combined rugby-conditioning and normal jump training program (control group). After the treatment period of 4 weeks, a crossover design was implemented by subjecting the control group to the treatment and allowing the initial experimental group to form the control group. The independent *t*-test and main effect ANOVA results showed that only relaxed upper-arm girth, ectomorphy, left Active-straight-leg-raise-test and the left Modified Thomas Quadriceps Test values showed significant differences ($p \leq 0.05$) when the two groups of players were compared. Therefore, a 4-week combined rugby-conditioning and resisted jump training program did not benefit university-level rugby players significantly more with regard to selected physical, motor ability and anthropometric components than a combined rugby-conditioning and normal jump training program.

KEY WORDS: plyometrics, resisted jump training, explosive power, anthropometry, rugby union

INTRODUCTION

Rugby, which is currently one of the most popular team sports in the world (21), is a sport that will probably benefit from the use of explosive, plyometric training due to the high levels of muscular power required by players during a game. Muscular power will enable players to break through tackles, accelerate fast from a static position and change running direction fast and effectively during attacks (21). One of the plyometric-related training methods that has received attention in recent years is loaded or resisted jump training (28). However, the broad spectrum of components rugby players need to develop to compete successfully in rugby games has forced rugby coaches and other conditioning experts to focus on combined rugby-conditioning programs which make use of a wide range of training methods rather than simplistic conditioning programs which only focus on one training modality at a time (28). Despite this contention, no researchers have until now investigated the effects of a combined sport-specific and resisted jump training program on the different components of team sport players.

Studies that have thus far investigated the effects of a resisted jump training program have focused on high school and Division 1 Collegiate athletes as well as students (25,31,32). In this regard a study on high school athletes of both genders for example showed that a combined resistance, sprint, Vertimax (resisted jump training device) plyometric and a normal plyometric training program of 12 weeks was significantly better ($p < 0.05$) in improving lower body peak power than a combined program, that did not include Vertimax training (31). The last-mentioned researchers also demonstrated that the same type of combined Vertimax program, as mentioned before, led to significantly better ($p < 0.05$) improvements in lower body peak power than a non-Vertimax plyometric-related combined program among Division 1 Collegiate athletes of both genders (32). The added benefit of a combined Vertimax program was attributed to a greater level of overload or increased localized stress placed on portions of the neuromuscular system which is not normally reached by conventional plyometric training (31).

In contrast with the previously mentioned study results, McClenton et al. (25) reported no significant changes in vertical-jump height when a 6-week Vertimax plyometric jump training program was performed by recreationally trained kinesiology students of both genders. However, they indicated that the group of students that performed depth jump training twice a week for the last-mentioned period, experienced significant ($p < 0.05$) increases in vertical jump height. The named researchers attributed the non-significant results to the increase in the amortization time

experienced during training due to the rubber band setup of the Vertimax training apparatus. Similarly, Carlson et al. (5) found no significant differences between the pre- and post-test vertical jump and predicted lower body power values of groups that performed a weight-training program only, a combined weight training and plyometric training program and a combined weight training and resisted jump training program, respectively.

One aspect that researchers have up until now not investigated are the possible changes in the anthropometric components of team sport players that may occur due to a combined sport-specific and resisted jump training program. This is quite surprising in view of the importance of players' anthropometric characteristics in determining playing positions and rugby performance (3). Research findings would, however, suggest that both bone mass and muscle fibre cross-sectional area can be improved by making use of load-bearing activities such as jumping (26). A bone and muscle mass-related characteristic, namely somatotype and especially the mesomorphic component, will probably also be influenced positively due to an increase in bone and muscle mass (4). In this regard, a combined sport-specific and resisted jump training program will probably benefit these anthropometric variables due to the load-bearing activities it contains. Also, because of the direct relationships between these anthropometric variables and power, which is a requirement for rugby (7,18), certain plyometric-related anthropometric changes would benefit rugby performance in the long run.

Considering the limited availability of research pertaining to the influence of a combined rugby-conditioning and resisted jump training program on selected physical, motor ability and anthropometric components of rugby players, the purpose of this investigation was to examine the effects of a 4-week combined rugby-conditioning and resisted jump training program compared to a combined rugby-conditioning and normal jump training program, on selected physical, motor ability and anthropometric components of university-level rugby players. Due to the limited availability of research articles on this topic, the results of this study may provide sport scientists, researchers and coaches with new information with regard to the use and effectiveness of combined rugby-conditioning and resisted jump training programs in improving certain physical, motor ability and anthropometric components among team sport participants.

METHODS

Experimental approach to the problem

To date, research has not given any attention to the possible benefits of combined sport-specific and resisted plyometric training programs for team sport participants. Therefore, it is unclear whether a combined sport-specific and resisted plyometric training program should be implemented and whether the benefits of resisted plyometric training observed in Division 1 Collegiate athletes as well as students, could be extended to team sports such as rugby union. However, despite a lack of research the specific hypothesis under scrutiny was that a 4-week combined rugby-conditioning and resisted jump training program will lead to significantly better changes ($p \leq 0.05$) in leg explosive power, speed, agility, lower body flexibility and muscle strength as well as body size, lean body, muscle, fat and skeletal mass as well as the somatotype of university-level rugby players compared to a combined rugby-conditioning and normal jump training program.

The study used a two-way randomized, pre- and post-test, crossover experimental design to investigate the adaptations of body composition, lower body flexibility, explosive leg power, speed, agility and leg strength to the combined training program. To determine whether there were changes in these last-mentioned variables, subjects were tested in-season (the season extended from March to the end of September) immediately before (the start of May) and after 4 weeks (mid-June) of either a combined sport-specific and resisted plyometric training program (experimental group) or a combined sport-specific and normal plyometric training program. After a 10-week period ("wash-out period" - mid-June to end of August) during which subjects continued with their normal rugby-conditioning program, the same testing procedures as before, were executed. A crossover design was implemented by subjecting the control group to 4 weeks of treatment (combined sport-specific and resisted plyometric training program) and allowing the other group to now execute the 4 week combined sport-specific and normal plyometric training program (control group). As before, subjects were again tested immediately after 4 weeks of combined training.

By obtaining measures of body composition (body mass and stature as well as fat, muscle and skeletal mass), flexibility (Passive-straight-leg-raise-test (PSLRT) and the Modified Thomas Quadriceps Test (MTQT)), explosive leg power (Vertical jump test (VJT), speed (5, 10 and 20m Speed test), agility (Illinois Agility Run Test (IART)) and leg strength (6RM repetition maximum)

Smith Machine Squat Test (SMST)) at 4 time points during the in-season period, researchers were enabled to determine how the players responded to the specific training programs.

Subjects

Thirty rugby players (19.60 ± 0.79 years) from the first and second u/19 and u/21 rugby teams of a university in South Africa were randomly selected to participate in the study. The thirty players were in turn randomly divided into two groups of fifteen players each. One group formed the experimental and the other group the control group. After the treatment period of 4 weeks, a crossover design was implemented by subjecting the control group to the treatment and allowing the initial experimental group to form the control group. The competitive rugby playing experience of these players varied between 2 and 12 years with an average of 8.60 years. Subjects gave written informed consent after having received both a verbal and a written explanation of the experimental protocol and its potential risks. The study was approved by the Ethics Committee of the institution where the research was conducted (NWU-0024-11-A1).

Subjects also completed a general information questionnaire regarding their exercising habits, injury incidence and competing level. Positionally, the group initially consisted of 15 backs (numbered nine to fifteen) and 15 forwards (numbered one to eight). Only eight subjects in the control group and twelve subjects in the experimental group executed all the tests, which meant that ten subjects were excluded from the study. This high fall-out of players was caused by injuries that players experienced during the course of the study.

Subjects volunteered to participate in the study and were healthy and free of any injuries during the time of testing and participation in the rugby-conditioning training programs. Each subject was instructed to sleep at least 8 hours during the evening and morning prior to the different testing sessions. They also had to abstain from ingesting any drugs or participating in strenuous physical activity that may influence the physical or physiological responses of the body for at least 48 hours before the scheduled tests. Subjects had to maintain the same diet during the weeks of testing. The subjects arrived at the testing sessions in a rested and fully hydrated state.

Training

All subjects were participating in the same rugby-conditioning program before, during and after the testing period. At the time of the study players were following an in-season program, that was conducted by the same sport scientists to ensure consistency in coaching techniques and programming. The program consisted of field sessions once a day and resistance training sessions three times a week with a duration of more or less 2 hours per training session each. The field sessions included skill activities, offensive and defensive drills as well as conditioning intervals. Resistance training sessions consisted of more or less 12 to 16 medium to high intensity resistance exercises (70-100% of the 1RM) with repetitions ranging from 1-6 (maximal strength: 85-100% of 1RM) and 8-12 (hypertrophy: 70-80% of 1RM) and primarily focused on the attainment of muscle hypertrophy (size with strength) and pure strength.

The experimental group also had to perform a 4-week resisted jump training program on the Vertimax (VertiMax Inc., Tampa, Florida) three times a week additional to their normal training program. Subjects performed 3 different exercises on a level 2 cord resistance of the Vertimax for 3 sets of 8 repetitions each during the first 2 weeks of training. During the following two weeks the repetitions were reduced to 6 repetitions while the sets remained on 3 and the resistance increased to level 3. The rest between sets and exercises was set at 2 minutes. This resting guideline was followed throughout the 4-week training period. The resisted plyometric training program is presented in Table 1. All control group subjects executed a normal plyometric training program during which three different exercises were performed for 3 sets of 8 repetitions each during the first two weeks of training after which the repetitions were reduced to 6 repetitions for the two weeks that followed. During the last two weeks the intensity of the exercises was also increased by increasing the heights or distances of the jumping exercises. This program was also performed three times a week and the rest between sets and exercises set at 2 minutes during the training period. This plyometric training program is presented in Table 2.

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TABLE 1. Four week long resisted jump training program compiled according to the guidelines of the Vertimax User's Manual (12)

Week	Day	Resisted jump training exercises	Sets x Repetitions	Resistance / Cord configuration
1	1	¼ Stick Jump	3×8	Two cords at a resistance of level 2
		Lunge Jump	3×8	
		Drop Jump	3×8	
	2	¼ Stick Jump	3×8	Two cords at a resistance of level 2
		Lunge Jump	3×8	
		Drop Jump	3×8	
	3	¼ Stick Jump	3×8	Two cords at a resistance of level 2
		Lunge Jump	3×8	
		Drop Jump	3×8	
2	1	¼ Stick Jump	3×8	Two cords at a resistance of level 2
		Lunge Jump	3×8	
		Drop Jump	3×8	
	2	¼ Stick Jump	3×8	Two cords at a resistance of level 2
		Lunge Jump	3×8	
		Drop Jump	3×8	
	3	¼ Stick Jump	3×8	Two cords at a resistance of level 2
		Lunge Jump	3×8	
		Drop Jump	3×8	
3	1	¼ Stick Jump	3×6	Two cords at a resistance of level 3
		Lunge Jump	3×6	
		Drop Jump	3×6	
	2	¼ Stick Jump	3×6	Two cords at a resistance of level 3
		Lunge Jump	3×6	
		Drop Jump	3×6	
	3	¼ Stick Jump	3×6	Two cords at a resistance of level 3
		Lunge Jump	3×6	
		Drop Jump	3×6	
4	1	¼ Stick Jump	3×6	Two cords at a resistance of level 3
		Lunge Jump	3×6	
		Drop Jump	3×6	
	2	¼ Stick Jump	3×6	Two cords at a resistance of level 3
		Lunge Jump	3×6	
		Drop Jump	3×6	
	3	¼ Stick Jump	3×6	Two cords at a resistance of level 3
		Lunge Jump	3×6	
		Drop Jump	3×6	

Rest between sets and exercises were 2 min.

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TABLE 2. Four week long plyometric training program

Week	Day	Normal jump training exercises	Sets x Repetitions	Resistance / Cord configuration
1	1	¼ Stick Jump	3×8	No Resistance
		Lunge Jump	3×8	
		Drop Jump	3×8	
	2	¼ Stick Jump	3×8	No Resistance
		Lunge Jump	3×8	
		Drop Jump	3×8	
	3	¼ Stick Jump	3×8	No Resistance
		Lunge Jump	3×8	
		Drop Jump	3×8	
2	1	¼ Stick Jump	3×8	No Resistance
		Lunge Jump	3×8	
		Drop Jump	3×8	
	2	¼ Stick Jump	3×8	No Resistance
		Lunge Jump	3×8	
		Drop Jump	3×8	
	3	¼ Stick Jump	3×8	No Resistance
		Lunge Jump	3×8	
		Drop Jump	3×8	
3	1	¼ Stick Jump	3×6	No Resistance
		Lunge Jump	3×6	
		Drop Jump	3×6	
	2	¼ Stick Jump	3×6	No Resistance
		Lunge Jump	3×6	
		Drop Jump	3×6	
	3	¼ Stick Jump	3×6	No Resistance
		Lunge Jump	3×6	
		Drop Jump	3×6	
4	1	¼ Stick Jump	3×6	No Resistance
		Lunge Jump	3×6	
		Drop Jump	3×6	
	2	¼ Stick Jump	3×6	No Resistance
		Lunge Jump	3×6	
		Drop Jump	3×6	
	3	¼ Stick Jump	3×6	No Resistance
		Lunge Jump	3×6	
		Drop Jump	3×6	

Rest between sets and exercises were 2 min.

Subjects were required to attend at least 100% of all training sessions and not join other types of fitness training programs to be included in the study. The 4-week training period was deemed to be sufficient due to the suggestion made by Luger and Pook (21) that the necessary mesocycle period for rugby players' training is 4-6 weeks. Furthermore, combined sport conditioning and plyometric training or combined resistance and plyometric training programs of 4 weeks seems to be

sufficient in causing significant improvements in speed (over 20-, 40- and 60-yd), standing broad jump and T-agility performances as well as vertical jump height and power, respectively among groups of trained baseball (8) and volleyball players (27).

Testing Procedures

A week before the official testing week, each player was subjected to the testing protocol. This was used to familiarize the players with the testing procedures. A week after the familiarization period the first testing day commenced. The players underwent four days of testing, namely two pre- and two post-test days respectively. On the first pre-test day players completed the questionnaire, together with the informed consent form, after which the anthropometric measurements and lower body flexibility measurements were taken. This was followed by the execution of an intensive dynamic rugby-specific warm-up for more or less 15 minutes. Explosive leg power, speed and acceleration as well as the agility and lower body muscle strength tests followed. All experimental group subjects were then subjected to four weeks of resisted jump training which was performed in conjunction with their normal rugby training program. The control group continued with their normal rugby-conditioning training program together with a normal plyometric training program for the 4-week period. Following the 4-week intervention the players were again tested at the exact time of day (post-test day) and same day of the week as the pre-test day to minimize the effect of circadian variations in test results. After the first treatment period, a crossover design was implemented by subjecting the control group to the treatment and allowing the initial experimental group to form the control group. As before, subjects were again tested immediately after 4 weeks of combined training.

Anthropometric measurements

The following anthropometric components were determined in accordance with the methods of Marfell-Jones et al. (22): body stature and mass as well as fat, muscle and skeletal mass. Body stature was recorded to the nearest 0.1 centimetre by means of a stadiometer (Harpenden portable stadiometer, Holtain Limited, UK.) and body mass was recorded to the nearest 0.1 kg with a portable electric scale (BFW 300 Platform scale, Adam equipment Co. Ltd., UK.). Body mass index (BMI) was determined by dividing the body weight (kg) of each player by the square root of the body stature (m) (16). The fat mass was analysed by using a Harpenden skinfold caliper (Holtain Limited, UK.) with a constant pressure of 10 g·mm⁻², to measure subcutaneous adipose tissue, and was calculated by means of the sum of the following skinfolds (SUM6SF): triceps,

subscapular, abdominal, supraspinal, front thigh and calf skinfolds according to the formulas of Withers et al. (35). Muscle and skeletal mass were calculated using the formulas of Lee et al. (20) and Martin et al. (as quoted by Drinkwater & Mazza, (9)). Ankle, femur, humerus and wrist breadths were measured by making use of a small sliding caliper (Holtain Bicondylar Calipers, Holtain Limited, UK.) and recorded to the nearest 0.1 cm. Relaxed and flexed arm, forearm, thigh and calf girth were taken with a Lufkin metal tape (Cooper Industries, U.S.A.) to the nearest 0.1 cm. All measurements were taken by the International Society for the Advancement of Kinanthropometry (ISAK) level 2 accredited anthropometrists on the right sides of the body. The technical error of measurement (TEM) was calculated by using the formulas of Pederson and Gore (1996), that revealed values of 3.41% (1.92 mm) for all skinfold measurements, 1.89% (0.43 cm) for all breadth measurements and 0.85% (1.31 cm) for all girth measurements (29).

Physical and motor ability components

The following laboratory tests were conducted to evaluate the physical and motor ability components:

Flexibility tests. The Passive-straight-leg-raise-test (PSLRT) was executed according to the method of Maud and Kerr (24). Players were asked to lie on a firm plinth in the supine position, with the arms at the sides of the body and the palms facing downward. The lower limbs were extended flat on the bench, while the sacrum stayed in contact with the surface of the plinth. The tester placed one hand on the anterior aspect of the non-test thigh to ensure that it stays in contact with the plinth. The other hand was placed under the calf of the test leg. The tester lifted the test leg while the knee was kept in total extension. The foot and ankle were relaxed. The leg was lifted until the maximum amount of hip flexion concurrent with full knee extension was achieved. A standard plastic goniometer was centred over the greater trochanter of the femur, with the mobile arm pointed towards the lateral epicondyle of the femur and the fixed arm aligned with the lateral midline of the pelvis. The same measurement was taken for the non-tested leg. Each measurement was taken twice. If a difference of more than 5° was observed between the two measurements, a third measurement was taken. The Active-straight-leg-raise-test (ASLRT) was executed in the exact same manner as the PSLRT with the difference that the player had to lift the test leg by himself while the knee was kept in total extension (14).

The Modified Thomas Quadriceps Test (MTQT) was executed according to the method of Harvey and Mansfield (14). The players were instructed to sit at the end of the plinth and lie back with both knees held to the chest, while the non-tested leg was held at the knee and at the same time held to the chest while the tested limb was lowered towards the floor. The player had to relax the hip and thigh muscles so that the passive end-point position could be obtained due to gravity alone. The angle of knee flexion of the tested limb that was lowered towards the floor was measured. A standard plastic goniometer was centered laterally at the knee joint line, the fixed arm aligned with the length of the femur towards the greater trochanter of the femur and the mobile arm pointed towards the lateral malleolus of the fibula. The same measurement was taken for the non-tested leg. Each measurement was taken twice. If a difference of more than 5° was observed between the two measurements, a third measurement was taken.

Explosive power, speed and acceleration, agility and leg strength tests. The vertical jump test (VJT) was executed in accordance with the method of Harman et al. (13). The VJT was performed by means of the Vertec device (Power Systems, Knoxville, Tennessee). Before commencement of the testing procedure, the height of the vertical column was adjusted so that the player could touch the movable vanes to register a standing touch height. Each player was instructed to stand with the dominant arm's shoulder and the dominant leg's foot under the coloured movable vanes. Keeping the heels on the floor, the player reached upwards as high as possible. The distance was recorded as the standing touch height to the nearest 0.5 cm. An arm swing and counter movement was used to jump as high as possible and to tap the highest possible vane. This distance was recorded and noted as the jumping distance. The difference between the standing touch height and jumping distance was calculated and recorded to the nearest 0.5 cm. The players performed a minimum of two trials with a 2-minute rest period between each trial. The better of the two trials was recorded. Power output during the vertical jump test was measured for each jump with a Tendo™ Power Output Unit (Tendo Sports Machines, Trencin, Slovak Republic). The Tendo™ unit consists of a transducer attached to the end of each player's waist and that measured linear displacement and time. Subsequently, jump velocity was calculated by means of which power was determined. Both peak and mean power outputs were recorded for each jump and used for the subsequent analyses. According to Hoffman et al. (17), the test-retest reliability of the Tendo unit is $r \geq 0.90$.

The sprint for a specific distance is seen as an objective, reliable and valid test to determine the speed of subjects (15). According to Ellis et al. (10), players rarely run further than 20 m in a

straight line in a game; hence the reason for a 20 m sprint test. Additionally, the last-mentioned authors also recommend that the standing start rather be used during execution of the 20 m test due to its sport specificity. Over the years numerous sports have also assessed acceleration with the 5 and 10 m split times (10). It is against this background that intermediate beam electronic timing gates (Brower Timing Systems, Utah, USA) were set at 0, 5, 10, and 20 m intervals on a section of the rugby field. The starting (0 m) and finishing line (20 m) were marked with cones. When players were ready they started from a standing position (thereby eliminating the possible influence of reaction time) with the front foot up to the starting line. The players were requested to sprint as fast as possible through the finish line, making sure not to slow down before the finish line. Split times (at 5 and 10 m) and final time (20 m) for three trials, with a 2-minute resting period between each, were recorded to the nearest 0.01 sec. The best times for 5, 10 and 20 m were used in the final analyses.

The players' agility was assessed using the Illinois Agility Run Test (IART). Intermediate beam electronic timing gates (Brower Timing Systems, Utah, USA) were used to take the players' times to the nearest 0.01 sec. The run started from a standing start on the command "Go" and players sprinted 9 m, turned, and returned to the starting line. When the players reached the starting line they zigzagged in between four markers and completed two 9 m sprints. The fastest time of the two trials was noted as the final agility time. A resting period of 2 min was allowed between trials. According to Gabbett (11), the intra-class correlation coefficient for the test-retest reliability and technical error of measurement for the IART are 0.86 and 2.02% respectively.

The leg strength was evaluated by using the 6RM (repetition maximum) Smith Machine Squat Test (SMST) as adapted from the testing method of Baechle et al. (2). The players were first instructed to warm up with a light resistance that allowed them to perform 11 to 16 repetitions. After a rest period of 1 minute the load was increased by 10-20 percent to allow the players to perform 9 to 10 repetitions. Another 2 minutes' rest period was allowed after which another 10-20 percent increase in load took place to allow the players to perform 7 to 8 repetitions. Players were provided with a 4-minute rest period after which they attempted to perform a 6RM with a 10-20% heavier weight. The weight was increased or decreased until the player could complete 6 repetitions with the proper exercise technique. The knee angle of each player was controlled to be 90° during the downward phase of the squat movement by centring a standard plastic goniometer laterally at the knee joint line with the fixed arm aligned with the length of the femur towards the

greater trochanter of the femur and the mobile arm pointed towards the lateral malleolus of the fibula. The Smith Machine stoppers were then set at the point where the bar position forced a player to bend his knee 90° during the downward phase of the movement.

Statistical Analysis

The Statistical Consultation Services of the institution where the research was conducted determined the statistical methods and procedures for the analyses of the research data. The Statistical Data Processing package (33) was used to process the data. The descriptive statistics (averages, standard deviations, minimum and maximum values) of each physical, motor ability and anthropometric component were firstly calculated. This was followed by the calculation of differences between each of the groups' pre- and post-program values. In another step a nested design ANOVA was performed to determine whether any of the variables displayed a transfer effect from one testing session to the next. In cases where a transfer effect was identified, the researchers used an independent *t*-test to determine the statistical significance of differences between the values of the two groups' variables. Finally, a main effect ANOVA provided the researchers with answers regarding the significance of a combined rugby-conditioning and resisted plyometric training program compared to a combined rugby-conditioning and normal plyometric training program on the different physical, motor ability and anthropometric components. The level of significance was set at $p \leq 0.05$.

RESULTS

Firstly, the descriptive statistics and the differences between the pre- and post-test results for the various groups regarding the selected physical, motor ability and anthropometric components are presented in Tables 3 and 4.

TABLE 3. Descriptive statistics and differences between the pre- and post-test results for the various groups regarding the selected anthropometric components

Group	Pre-test	Post-test	Difference between pre- and post-tests
Body weight (kg)			
Control group (n = 20)	90.58 ± 15.52	90.26 ± 15.99	-0.32 ± 1.40
Experimental group (n = 20)	90.65 ± 15.74	90.37 ± 15.97	-0.28 ± 1.18
Body stature (cm)			
Control group (n = 20)	181.06 ± 8.35	181.13 ± 8.49	0.22 ± 0.31
Experimental group (n = 20)	180.75 ± 8.30	181.19 ± 8.24	0.48 ± 0.40
BMI (kg·m⁻²)			
Control group (n = 20)	27.51 ± 3.54	27.37 ± 3.52	0.14 ± 0.44
Experimental group (n = 20)	27.59 ± 3.41	27.38 ± 3.54	0.21 ± 0.44
Biceps SF (mm)			
Control group (n = 20)	5.49 ± 2.28	5.80 ± 2.72	0.27 ± 1.11
Experimental group (n = 20)	5.64 ± 2.58	5.78 ± 2.99	0.15 ± 1.32
Triceps SF (mm)			
Control group (n = 20)	10.59 ± 5.57	10.99 ± 5.67	0.40 ± 1.88
Experimental group (n = 20)	11.31 ± 5.61	10.96 ± 5.86	-0.35 ± 1.79
Subscapular SF (mm)			
Control group (n = 20)	12.29 ± 5.49	12.83 ± 6.13	0.54 ± 1.36
Experimental group (n = 20)	12.70 ± 5.52	12.69 ± 5.98	-0.01 ± 1.88
Supraspinal SF (mm)			
Control group (n = 20)	12.04 ± 7.95	12.36 ± 8.27	0.32 ± 2.46
Experimental group (n = 20)	11.82 ± 7.19	11.55 ± 7.11	-0.28 ± 1.20
Abdominal SF (mm)			
Control group (n = 20)	16.53 ± 9.60	16.55 ± 10.06	0.03 ± 3.61
Experimental group (n = 20)	16.95 ± 9.89	16.05 ± 9.43	-0.90 ± 1.99
Thigh SF (mm)			
Control group (n = 20)	13.91 ± 7.05	14.18 ± 7.83	0.28 ± 2.23
Experimental group (n = 20)	14.59 ± 7.32	13.41 ± 6.19	-1.18 ± 4.71
Calf SF (mm)			
Control group (n = 20)	10.47 ± 5.73	10.08 ± 5.53	-0.40 ± 1.93
Experimental group (n = 20)	10.21 ± 4.74	9.89 ± 4.97	-0.32 ± 1.68
SUM6SF (mm)			
Control group (n = 20)	75.82 ± 38.48	76.98 ± 40.81	1.16 ± 8.23
Experimental group (n = 20)	77.57 ± 37.45	74.54 ± 36.17	-3.03 ± 6.06
Humerus girth (cm)			
Control group (n = 20)	7.11 ± 0.38	7.12 ± 0.40	0.01 ± 0.24
Experimental group (n = 20)	7.06 ± 0.38	7.03 ± 0.40	-0.04 ± 0.22
Wrist girth (cm)			
Control group (n = 20)	5.40 ± 0.43	5.45 ± 0.46	0.05 ± 0.21
Experimental group (n = 20)	5.41 ± 0.38	5.39 ± 0.49	-0.02 ± 0.21
Femur girth (cm)			
Control group (n = 20)	9.86 ± 0.64	9.85 ± 0.55	-0.01 ± 0.24
Experimental group (n = 20)	9.83 ± 0.53	9.89 ± 0.67	0.06 ± 0.23

Values presented as mean ± SD; BMI = Body mass index; SF = Skinfold; SUM6SF = sum of 6 skinfolds

TABLE 3 (cont). Descriptive statistics and differences between the pre- and post-test results for the various groups regarding the selected anthropometric components

Group	Pre-test	Post-test	Difference between pre- and post-tests
Ankle girth (cm)			
Control group (n = 20)	7.34 ± 0.57	7.28 ± 0.48	-0.06 ± 0.31
Experimental group (n = 20)	7.43 ± 0.54	7.49 ± 0.55	0.06 ± 0.27
Relaxed upper-arm girth (cm)			
Control group (n = 20)	35.00 ± 3.02	35.23 ± 3.12	0.23 ± 0.84
Experimental group (n = 20)	35.42 ± 3.14	35.01 ± 3.14	-0.41 ± 0.82
Flexed upper-arm girth (cm)			
Control group (n = 20)	38.24 ± 2.75	38.21 ± 2.72	-0.03 ± 0.59
Experimental group (n = 20)	38.25 ± 2.89	38.35 ± 3.05	0.10 ± 0.72
Thigh girth (cm)			
Control group (n = 20)	59.18 ± 5.75	59.53 ± 5.65	0.35 ± 1.33
Experimental group (n = 20)	59.41 ± 5.82	59.20 ± 5.74	-0.21 ± 1.55
Calf girth (cm)			
Control group (n = 20)	39.66 ± 3.22	39.45 ± 4.26	-0.21 ± 2.89
Experimental group (n = 20)	38.24 ± 6.53	39.37 ± 3.20	1.13 ± 6.18
Forearm girth (cm)			
Control group (n = 20)	30.25 ± 1.52	30.19 ± 2.00	-0.06 ± 0.77
Experimental group (n = 20)	30.29 ± 1.65	30.28 ± 1.72	-0.01 ± 0.41
Fat percentage (%)			
Control group (n = 20)	12.74 ± 6.07	12.93 ± 6.43	0.019 ± 1.30
Experimental group (n = 20)	13.01 ± 5.91	12.53 ± 5.68	-0.48 ± 0.95
Fat mass (kg)			
Control group (n = 20)	12.20 ± 7.64	12.38 ± 7.86	0.18 ± 1.38
Experimental group (n = 20)	12.45 ± 7.45	12.02 ± 7.26	-0.43 ± 0.84
Muscle mass percentage (%)			
Control group (n = 20)	52.37 ± 8.88	52.68 ± 9.43	0.31 ± 2.56
Experimental group (n = 20)	51.96 ± 8.87	52.57 ± 8.73	0.61 ± 3.30
Muscle mass (kg)			
Control group (n = 20)	48.64 ± 15.98	48.83 ± 16.65	0.19 ± 2.80
Experimental group (n = 20)	48.31 ± 15.76	48.77 ± 16.17	0.47 ± 3.57
Skeletal mass percentage (%)			
Control group (n = 20)	9.66 ± 1.50	9.65 ± 1.49	-0.01 ± 0.41
Experimental group (n = 20)	9.65 ± 1.42	9.73 ± 1.56	0.07 ± 0.34
Skeletal mass (kg)			
Control group (n = 20)	8.93 ± 2.70	8.89 ± 2.71	-0.05 ± 0.41
Experimental group (n = 20)	8.92 ± 2.63	8.99 ± 2.84	0.07 ± 0.41
Endomorphy			
Control group (n = 20)	3.20 ± 1.62	3.31 ± 1.71	0.10 ± 0.39
Experimental group (n = 20)	3.31 ± 1.58	3.23 ± 1.63	-0.08 ± 0.37
Mesomorphy			
Control group (n = 20)	6.01 ± 0.96	5.97 ± 0.98	-0.05 ± 0.65
Experimental group (n = 20)	5.76 ± 1.24	5.92 ± 0.99	0.16 ± 0.99
Ectomorphy			
Control group (n = 20)	1.43 ± 0.91	1.42 ± 0.91	-0.00 ± 0.03
Experimental group (n = 20)	1.38 ± 0.90	1.41 ± 0.89	0.03 ± 0.05

Values presented as mean ± SD

The pre- to post-test changes with regard to the body fat-related measurements (Table 3) show that the experimental group experienced decreases in six out of a possible seven skinfolds as well as the sum of six skinfolds, body fat mass and percentage due to the combined resisted jump training and rugby-conditioning program, compared to the control group who only experienced a decrease in one of the skinfolds and increases in all of the other body fat-related measurements. With regard to the skeletal and muscle mass-related measurements, both groups experienced decreases in five out of a possible nine girth measurements and increases in the muscle mass and percentage values. However, the control group experienced decreases in skeletal mass and percentage values whereas the experimental group experienced increases in these last-mentioned values. The combined normal jump training and rugby-conditioning program (control group) led to decreases in the mesomorphy and ectomorphy values and an increase in the endomorphy value, whereas the combined resisted jump training and rugby-conditioning program (experimental group) led to increases in the mesomorphy and ectomorphy values and a decrease in the endomorphy value. Despite the differences in the above-mentioned changes by the two groups, both groups experienced decreases in body mass and increases in body stature as well as BMI during the training period.

An analysis of the physical and motor ability components (Table 4) revealed that all the flexibility-related components showed improvements in the experimental group, whereas the control group only experienced an improvement in the average left Passive-straight-leg-raise-test value and decreases in the rest of the flexibility-related variables. Despite the fact that the experimental group displayed a small increase in the VJT height due to the conditioning program, the VJT Tendo peak power showed a decrease but the VJT Tendo speed an increase. Similarly, the control group experienced a decrease in VJT Tendo peak power even though their VJT height showed an increase due to the 4-week conditioning program. However, in this group the VJT Tendo speed also showed a decrease due to the conditioning program. Unexpectedly, the experimental group experienced an increase in all the speed-related times, compared to the control group who showed decreases in all of the times. Both groups did, however, display improvements in the Illinois agility times and the 6RM SMST weight and relative weight due to the different conditioning programs.

Chapter 3:
The effects of a combined resisted jump training and rugby conditioning program on selected physical, motor ability and anthropometric components of rugby players

TABLE 4. Descriptive statistics and differences between the pre- and post-test results for the various groups regarding the selected physical and motor ability components

Group	Pre-test	Post-test	Difference between pre- and post-tests
L: PSLRT (°)			
Control group (n = 20)	86.10 ± 11.76	83.90 ± 8.81	-2.20 ± 10.27
Experimental group (n = 20)	87.95 ± 13.11	82.20 ± 8.85	-5.75 ± 10.45
R: PSLRT (°)			
Control group (n = 20)	83.45 ± 12.60	84.15 ± 9.46	0.70 ± 11.29
Experimental group (n = 20)	88.75 ± 11.53	85.65 ± 9.35	-3.10 ± 8.52
L: ASLRT (°)			
Control group (n = 20)	92.60 ± 8.86	93.55 ± 7.74	0.95 ± 10.78
Experimental group (n = 20)	98.60 ± 6.54	92.40 ± 6.79	-6.20 ± 6.65
R: ASLRT (°)			
Control group (n = 20)	93.75 ± 9.49	94.25 ± 8.83	0.50 ± 8.43
Experimental group (n = 20)	96.30 ± 9.51	93.95 ± 6.43	-2.35 ± 9.64
L: MTQT (°)			
Control group (n = 20)	66.90 ± 16.43	66.60 ± 13.48	-0.30 ± 12.88
Experimental group (n = 20)	61.70 ± 14.47	68.30 ± 13.29	6.60 ± 9.67
R: MTQT (°)			
Control group (n = 20)	69.55 ± 13.74	67.80 ± 9.82	-1.75 ± 11.96
Experimental group (n = 20)	68.50 ± 14.15	71.05 ± 13.94	2.55 ± 8.53
VJT height (cm)			
Control group (n = 20)	50.05 ± 7.73	53.15 ± 10.91	3.10 ± 7.59
Experimental group (n = 20)	52.03 ± 8.35	52.20 ± 9.86	0.18 ± 4.16
VJT Tendo peak power (W)			
Control group (n = 20)	2904.30 ± 533.42	2670.85 ± 383.55	233.45 ± 361.55
Experimental group (n = 20)	2755.95 ± 400.81	2731.55 ± 540.60	244.00 ± 363.78
VJT Tendo speed (m·s ⁻¹)			
Control group (n = 20)	3.15 ± 0.18	3.05 ± 0.31	-0.10 ± 0.24
Experimental group (n = 20)	3.13 ± 0.24	3.16 ± 0.24	0.03 ± 0.22
5m Speed (s)			
Control group (n = 20)	1.14 ± 0.06	1.12 ± 0.09	-0.03 ± 0.09
Experimental group (n = 20)	1.10 ± 0.08	1.13 ± 0.07	0.03 ± 0.10
10m Speed (s)			
Control group (n = 20)	1.91 ± 0.07	1.87 ± 0.11	-0.04 ± 0.09
Experimental group (n = 20)	1.87 ± 0.10	1.88 ± 0.09	0.01 ± 0.08
Illinois agility (s)			
Control group (n = 20)	15.31 ± 0.71	15.06 ± 0.69	-0.26 ± 0.22
Experimental group (n = 20)	15.32 ± 0.81	15.07 ± 0.72	-0.26 ± 0.41
6RM SMST weight (kg)			
Control group (n = 20)	141.75 ± 24.02	156.00 ± 21.86	14.25 ± 20.98
Experimental group (n = 20)	148.75 ± 21.51	157.75 ± 22.03	9.00 ± 11.31
Relative 6RM SMST weight (6RM·body weight ⁻¹)			
Control group (n = 20)	1.61 ± 0.37	1.77 ± 0.31	0.16 ± 0.21
Experimental group (n = 20)	1.68 ± 0.34	1.79 ± 0.35	0.11 ± 0.13

Values presented as mean ± SD; L = Left; R = Right; PSLRT = Passive-straight-leg-raise-test; ASLRT = Active-straight-leg-raise-test; MTQT = Modified Thomas Quadriceps Test; VJT = Vertical jump test; 6RM SMST = Six repetition maximum Smith Machine Squat Test

Before interpreting the above-mentioned results, the researchers first needed to determine which of the above-mentioned changes were statistically significant. However, due to the fact that a cross-over design was implemented, the researchers also had to consider the possibility that a transfer effect from one testing period to the next may have influenced the results. Therefore, a nested design ANOVA was performed to determine whether any of the variables displayed a transfer effect from one testing period to the next. The results of this analysis are presented in Tables 5 and 6.

TABLE 5. The nested ANOVA results of the anthropometric components

Variables	Treatment order	
	F-value	<i>p</i> -value
Body weight (kg)	0.01	0.92
BMI (kg·m ⁻²)	0.25	0.62
Biceps SF (mm)	0.16	0.75
Triceps SF (mm)	1.6	0.21
Subscapular SF (mm)	1.12	0.23
Supraspinal SF (mm)	0.93	0.34
Abdominal SF (mm)	0.10	0.32
Thigh SF (mm)	1.56	0.22
Calf SF (mm)	0.02	0.90
SUM6SF (mm)	3.35	0.07
Humerus girth (cm)	0.38	0.54
Wrist girth (cm)	0.93	0.34
Femur girth (cm)	0.78	0.38
Ankle girth (cm)	1.55	0.22
Relaxed upper-arm girth (cm)	5.74	0.02*
Flexed upper-arm girth (cm)	0.39	0.54
Thigh girth (cm)	1.50	0.23
Calf girth (cm)	0.77	0.39
Forearm girth (mm)	0.06	0.80
Fat percentage (%)	3.42	0.07
Fat mass (kg)	2.81	0.10
Muscle mass percentage (%)	0.10	0.75
Muscle mass (kg)	0.07	0.79
Skeletal mass percentage (%)	0.45	0.50
Skeletal mass (kg)	0.80	0.37
Endomorphy	2.33	0.13
Mesomorphy	0.60	0.44
Ectomorphy	8.06	0.01*

Values presented as mean $\pm$ SD; BMI = Body mass index; SF = Skinfold; SUM6SF = sum of the 6 skinfolds; * Transfer effect from one testing period to the next ($p \leq 0.05$).

Only two of the anthropometric variables showed a transfer effect from one testing period to the next, namely relaxed upper arm girth and ectomorphy. Due to the transfer effect an independent *t*-test was performed to determine the statistical significance of differences between these variables

of the rugby player groups (control and experimental) for the first testing period. The results of this test showed that relaxed upper-arm girth showed a significantly higher reduction due to the conditioning program in the experimental group than the control group. In contrast, the experimental group experienced a significantly higher increase in ectomorphy than the control group during participation in the conditioning program.

TABLE 6. The nested ANOVA results of the physical and motor ability components

Variables	Treatment order	
	F-value	<i>p</i> -value
L: PSLRT (°)	1.17	0.29
R: PSLRT (°)	1.44	0.24
L: ASLRT (°)	6.38	0.01*
R: ASLRT (°)	0.99	0.33
L: MTQT (°)	3.68	0.06
R: MTQT (°)	1.71	0.20
VJT height (cm)	2.29	0.14
VJT Tendo peak power (W)	3.32	0.08
VJT Tendo speed (m.s ⁻¹)	3.21	0.08
5m Speed (s)	3.27	0.08
10m Speed (s)	3.49	0.07
Illinois agility (s)	0.00	0.96
6RM SMST weight (kg)	0.97	0.33
Relative 6RM SMST weight (6RM·body weight ⁻¹)	0.90	0.35

Values presented as mean $\pm$ SD; L = Left; R = Right; PSLRT = Passive-straight-leg-raise-test; ASLRT = Active-straight-leg-raise-test; MTQT = Modified Thomas Quadriceps Test; VJT = Vertical jump test; 6RM SMST = Six repetition maximum Smith Machine Squat Test; * Transfer effect from one testing period to the next ($p \leq 0.05$).

The results in Table 6 show that only the left Active-straight-leg-raise-test results showed a transfer effect from one testing period to the next. The independent *t*-test revealed that the last-mentioned variable showed a significantly higher increase in the average score of the experimental than the control group.

The remaining variables that did not display a transfer effect were included in the main effect ANOVA as to provide the researchers with answers regarding the significance of a combined rugby-conditioning and resisted plyometric (jump) training program compared to a combined rugby-conditioning and normal plyometric (jump) training program on the different physical, motor ability and anthropometric components. The results of this analysis are provided in Table 7.

The effects of a combined resisted jump training and rugby conditioning program on selected physical, motor ability and anthropometric components of rugby players

TABLE 7. Results of the main effect ANOVA of physical, motor ability and anthropometric components

Variables	Treatment	
	F-value	p-value
Weight (kg)	0.29	0.60
BMI (kg·m ⁻²)	0.00	0.95
Biceps SF (mm)	0.01	0.93
Triceps SF (mm)	0.74	0.40
Subscapular SF (mm)	0.67	0.43
Supraspin SF (mm)	0.33	0.57
Abdomen SF (mm)	1.15	0.30
Thigh SF (mm)	3.01	0.10
Calf SF (mm)	0.15	0.70
Humerus girth(cm)	0.34	0.56
Wrist girth (cm)	0.68	0.42
Femur girth(cm)	1.53	0.23
Ankle girth (cm)	1.95	0.18
Flexed arm girth (cm)	2.46	0.13
Thigh girth (cm)	0.69	0.42
Calf girth (cm)	0.46	0.51
Fore-arm girth (mm)	0.22	0.65
SUM6SF (mm)	2.88	0.11
Fat percentage (%)	2.99	0.10
Fat mass (kg)	2.75	0.11
Muscle mass percentage (%)	0.15	0.70
Muscle mass (kg)	0.16	0.70
Skeletal mass percentage (%)	1.51	0.23
Skeletal mass (kg)	2.95	0.10
Endomorph	1.31	0.27
Mesomorph	0.54	0.47
L: PSLRT (°)	0.82	0.38
R: PSLRT (°)	1.82	0.19
R: ASLRT (°)	0.49	0.49
L: MTQT(°)	6.71	0.02*
R: MTQT (°)	1.37	0.26
VJT height (cm)	2.06	0.17
VJT Tendo peak power (W)	2.10	0.16
VJT Tendo speed (m.s ⁻¹)	2.58	0.13
5m Speed (s)	1.76	0.20
10m Speed (s)	2.01	0.17
Illinois agility(s)	0.01	0.92
6RM Squat (kg)	1.37	0.26
Relative 6RM SMST weight (6RM·body weight ⁻¹)	1.37	0.26

Values presented as mean ± SD; BMI = Body mass index; SF = Skinfold; SUM6SF = sum of the 6 skinfolds L = Left; R = Right; PSLRT = Passive-straight-leg-raise-test; ASLRT = Active-straight-leg-raise-test; MTQT = Modified Thomas Quadriceps Test; VJT = Vertical jump test; 6RM SMST = Six repetition maximum Smith Machine Squat Test; * Significant difference between the components of the experimental and control group ($p \leq 0.05$).

Surprisingly, only the left Modified Thomas Quadriceps Test value obtained significance with the experimental group that demonstrated a significantly better average flexibility score in this test than the control group. No other significant changes were observed.

DISCUSSION

In view of the fact that to date research has given no attention to the possible benefits of combined sport-specific and resisted plyometric training program for team-sport participants, the purpose of this study was to examine the effects of a 4-week combined rugby-conditioning and resisted jump training program (experimental group) compared to combined rugby-conditioning and normal jump training program (control group), on the selected physical, motor ability and anthropometric components of university-level rugby players. Although the overall study results suggest that the experimental group experienced more positive changes, especially with regard to the body fat, skeletal mass and somatotype-related anthropometric and flexibility-related measurements, only relaxed upper-arm girth, ectomorphy, left Active-straight-leg-raise-test and the left Modified Thomas Quadriceps Test values showed significant differences ($p \leq 0.05$) when the two groups of players were compared. Although the experimental group demonstrated significantly better average scores in the majority of the last-mentioned components, the experimental group experienced a significantly higher reduction in relaxed upper-arm girth due to the conditioning program than the control group. Therefore, the study did not succeed in showing that a 4-week combined rugby-conditioning and resisted jump training program will lead to significantly better changes in leg explosive power, speed, agility, lower body flexibility and muscle strength as well as body size, lean body, muscle, fat and skeletal mass as well as the somatotype of university-level rugby players than a combined rugby-conditioning and normal jump training program.

It is difficult to draw comparisons between the findings of this study and those of similar studies due to the fact that no other studies used a two-way randomized, pre- and post-test, crossover experimental design or a group of rugby players as subjects to conduct a study of this nature. As mentioned before, studies that have thus far investigated the effects of a resisted jump training program have focused on high school and Division 1 Collegiate athletes as well as students (25,31,32). However, only two of these studies found a combined resistance, sprint, resisted jump training plyometric and a normal plyometric training program of 12 weeks to be significantly better ($p < 0.05$) in improving lower body peak power than a combined program that did not include resisted jump training among high school and Division 1 Collegiate athletes of both

genders (31). Similarly to what was found in the current study, McClenton et al. (25) also reported no significant changes in vertical-jump height when a 6-week resisted jump training plyometric program was performed by recreationally trained kinesiology students of both genders. Neither were significant differences observed by Carlson et al. (5) when the pre- and post-test vertical jump and predicted lower body power values between groups that performed a weight-training program only, a combined weight training and jump training program and a combined weight training and resisted jump training program, respectively were compared.

In this study the only difference in the two types of program players were subjected to, was that the one program included resisted jump training plyometric exercises whereas the other program made use of normal jump training plyometric exercises. The above-mentioned results would suggest that the use of resisted jump training in a rugby-conditioning program does not provide significantly more benefits than when normal jump training is used. The only components which seem to benefit from a combined resisted jump training rugby-conditioning program are the flexibility-related components. In this regard, the passive quadriceps and active hamstring flexibility of the left leg showed significantly better improvements due to the combined resisted jump training than the combined normal jump training rugby-conditioning program. Although the design of this study did not allow the researchers to determine the reasons underlying the significant improvements in upper-leg muscle flexibility due to the combined resistance jump training program, several possible reasons may be provided:

Firstly, the extra resistance and overload players are subjected to while performing resisted jump training may possibly lead to more stress on the neuromuscular system (31) and especially the proprioceptors involved during the execution of plyometric exercises. The VertiMax system works such that the resistance bands fully retract into the system, which means that the tension of the resistance bands never decreases while the players are performing the jumping exercises. The players will, therefore, experience extra tension during both the eccentric and concentric phase of the jumping movement. Research suggests that the muscle-tendon complex may possibly experience changes due to plyometric training (19). In this regard Kubo et al. (19) concluded that a 12-week long plyometric training program led to significant increases in maximal tendon elongation and the amount of stored elastic energy. Furthermore, researchers also pointed out that a more compliant musculotendinous unit is more efficient when performing stretch-shortening cycle type of activities such as jumping exercises (34). In this regard a more compliant tendon will

possibly lead to relatively less myofibrillar displacement so that less linear extension is imposed on a muscle in series (34). Therefore, a more compliant tendon will ultimately lead to enhanced tendon recoil (34). In view of this explanation it is possible that the period of resisted jumping exercises led to an accentuated eccentric phase (downward phase of the jump) which may have forced the musculotendinous unit of the quadriceps to stretch dynamically against a high resistance. Over time this possibly would lead to a more compliant musculotendinous unit, which may explain the significantly better improvements for the passive quadriceps flexibility of the left leg due to the combined resisted jump training than the combined normal jump training rugby-conditioning program. However, this contention must be considered to be speculative due to the fact that it was not directly measured.

On the other hand, the significantly better active hamstring flexibility results of the experimental group may possibly be related to improved inter-muscular coordination (23) between the quadriceps and hamstring of the left leg. In this regard a review study by Markovic and Mikulic (23) revealed that plyometric training in combination with other training modalities may lead to improved inter-muscular coordination among sport participants. The range of motion during the Active-straight-leg-raise-test does not only depend on the elasticity of the musculotendinous unit of the hamstring muscle but also on the capacity of the quadriceps to cause hip flexion so that the leg can be extended vertically. Compared to the control group, the experimental group had to perform the concentric phase of the jumping exercises against the load of the resistance bands, which would force the quadriceps to produce more explosive power than would have been the case without the resistance bands. The twelve combined resisted jump training sessions completed after the 4-week training period could possibly have enabled the experimental group to use and contract the quadriceps more forcefully during the active hamstring flexibility test than the control group. According to Alter (1), a muscle that contracts (agonist) forcefully will lead to the inhibition of the opposing muscle (antagonist) by causing reciprocal innervation. It is, therefore, possible that the more forceful contraction of the quadriceps led to inhibition of the hamstring so that the hamstring could relax and stretch more during the active hamstring flexibility test. However, this contention must also be considered to be speculative due to the fact that it was not directly measured.

The outcome of the anthropometric components-related results revealed that relaxed upper-arm girth showed a significantly higher reduction due to the conditioning program in the experimental group than in the control group. The relaxed upper-arm is, amongst other things, determined by the

subcutaneous fat of the upper-arm measured by means of the biceps and triceps skinfolds. The control group showed an increase of 0.27 and 0.40 mm compared to an increase of 0.15 and a decrease of 0.35 mm for the two named skinfolds respectively in the experimental group. These differences in the size of the two skinfold measurements may explain the significant differences between changes in relaxed upper-arm girth in the two groups of players.

The experimental group experienced decreases in six out of a possible seven skinfolds as well as the sum of six skinfolds, body fat mass and percentage due to the combined resisted jump training and rugby-conditioning program compared to the control group who only experienced a decrease in one of the skinfolds and increases in all of the other body fat-related measurements. In contrast, the experimental group experienced a significantly higher increase in ectomorphy than the control group during participation in the conditioning program. Ectomorphy, which gives an indication of the relative linearity or slenderness of a person's physique (6), will increase as the players' body fat-related measurements decrease. From the last-mentioned discussion it is clear that the players in the experimental group experienced decreases in all the body fat-related measurements compared to the control group who only experienced a decrease in one of the body fat-related measurements which would explain the significant differences in ectomorphy values.

Hence all of the above-mentioned results suggest that only the minority of the selected physical, motor ability and anthropometric components of university-level rugby players showed significantly different changes when the effects of a 4-week combined rugby-conditioning and resisted training program were compared to combined rugby-conditioning and normal jump training program. The lack of significant differences between the two programs may be related to the rather short training period (4 weeks) the players were subjected to. Although the 4-week training period was deemed to be sufficient by researchers in causing significant improvements in a variety of physical and motor ability components of team sport participants (8,21,27), other studies on rugby players seem to suggest that a 4-week combined rugby-conditioning and plyometric training program may only lead to neural adaptations and not to morphological changes (30). Therefore, it can be recommended that longer training periods be used in future studies of this nature, especially where changes in the anthropometric profile of rugby players are the focus.

Another factor to consider when interpreting the results is that the players in this study were all used to plyometric training and their muscles were, therefore, already accustomed to land-based

plyometric type of explosive exercises before the start of the intervention period. All the players had been subjected to a general rugby-conditioning program for six months prior to the intervention period. Despite the fact that they were not used to resisted jump training type of programs, their neuromuscular systems would probably not be as sensitive and reactive to combined sport-specific plyometric conditioning programs as those of players that were untrained and not accustomed to this type of training. It is, therefore, important to consider players' experience in plyometric type of programs and training when planning a study of this nature.

One possible reason that the experimental group did not obtain more benefits with regard to their physical, motor ability and anthropometric profile than the control group is that the resisted jump training apparatus (VertiMax) may possibly lead to longer amortization times during the execution of the jumps (25). As has been explained earlier, the resistance band-setup of the VertiMax will lead to extra tension during both the eccentric and concentric phase of the jumping movements. However, the extra load placed on the legs during execution of the jumping exercises may be detrimental to the development of explosive power due to the fact that the transition time from eccentric to concentric muscle contractions (amortisation phase) is prolonged.

The non-significant results with regard to the measured components of this study can also possibly be attributed to the high fall-out of players during the course of the study. The groups of players that were tested were smaller than originally planned and could have caused outliers to have influenced the mean values of the respective test scores and anthropometric measurements more than would have been the case with larger group sizes. However, the use of a two-way randomized, pre- and post-test, crossover experimental design in this study, ensured that all players were objected to the same number and type of training sessions for the same periods of time. The implementation of this study design reduces the influence of confounding covariates because every player served as his own control which meant that smaller group sizes could be used.

To conclude, the study revealed that a 4-week combined rugby-conditioning and resisted training program (experimental group) did not benefit university-level rugby players significantly more with regard to selected physical, motor ability and anthropometric components than a combined rugby-conditioning and normal jump training program (control group). Therefore, the results suggest that further research be done to verify the use and effectiveness of combined sport-specific

and resisted training program compared with sport-specific program that do not make use of a resisted jump training apparatus (VertiMax). Furthermore, it can also be advised that future studies need to investigate the exact neural and musculoskeletal mechanisms that underlie the possible physiological benefits to be derived from resisted jump training programs.

PRACTICAL APPLICATIONS

These study results suggest that the combined rugby-conditioning and resisted jump training program executed in this study did not provide significantly more benefits ($p \leq 0.05$) with regard to the physical, motor ability and anthropometric profile of university-level rugby players than a combined training program that only utilized normal plyometric training exercises. These results, therefore, cast a shadow of doubt on the contention that the use of resisted jump training will be more beneficial than the use of normal jump training when a combined rugby-specific program is implemented. However, it is possible that players need to perform these types of programs for a longer period of time in order to adapt to the new training program and to reap the benefits these type of programs may hold. Furthermore, combined rugby-conditioning and resisted jump training program will probably benefit players more with regard to their physical, motor ability and anthropometric profile if they are compiled according to each player's initial strength levels. The cords of the Vertimax resistance training apparatus can then be set according to a certain percentage of the player's strength levels in order to individualize the training load. It will probably also be advisable to determine at which load each player is able to perform the jump training exercises in such a way that the transition time from eccentric to concentric muscle contractions (amortisation phase) is kept short. Despite these shortcomings and recommendations the study results provide insight into an area no other researchers have focused on.

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