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Original research

Comparison of resistance training progression models on maximal strength in sub-elite adolescent rugby union players

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ABSTRACT

Objectives: To determine changes in maximal strength between two different resistance training progression models, linear (LP) and daily undulating (DUP), over a 12-week resistance training programme in sub-elite adolescent rugby union players.
Design: The study used a quasi-experimental study design. Following baseline assessments, participants from Squad 1 were randomised to either LP or DUP; participants from Squad 2 formed a non-randomised comparison group (CON).
Methods: Participants were 26 sub-elite adolescent rugby union players who were assessed at baseline and after 12 weeks. Outcomes included 5 repetition maximum (RM) box squat and bench press, height, body weight, skeletal muscle mass, percentage body fat and maturation status.
Results: Participants in both the LP and DUP groups significantly increased their squat and bench press strength from baseline to 12 weeks. There were no significant differences between groups for squat and bench press increases after 12 weeks ($p > 0.05$). No significant increases in squat or bench press strength were observed after 12 weeks in the CON group. Increases in lower body strength were large in the LP group (ES: 1.64) and very large in the DUP group (ES: 2.33). Upper body strength changes were small in both groups (LP, ES: 0.57; DUP, ES: 0.31).
Conclusions: Twelve weeks of LP or DUP resistance training are both effective at increasing maximal lower and upper body strength in adolescent rugby athletes. Additionally, twice weekly frequency of resistance training in adolescent rugby athletes with greater than 6-months resistance training experience is sufficient to elicit substantial increases in maximal strength.

1. Introduction

Rugby union is a physical, tactical and skill-based, team sport requiring participants to have a range of physical qualities.[1,2] It is characterised by repeated high-intensity sprints and frequent player contact situations, including rucks, scrums, and mauls.[1,2] A number of relationships between physical characteristics and playing level have been established demonstrating that elite level players exhibit superior levels of strength, power, speed, height, and body mass.[2,3] compared to lower level players. Increasing the strength, power and anthropometric characteristics of lower level players is essential to enhance the likelihood of participation at higher levels.[3] Resistance training forms an integral component in the physical preparation of rugby players,[4] and with increased popularity of the theorised potential benefits of a long term approach to athletic development,[5] it is more often being performed by adolescents involved in sub-elite or representative talent development programmes.

Appropriately supervised resistance training promotes extensive health and fitness adaptations[6,7] with previous reviews and position papers dispelling concerns regarding the safety of resistance training for children and adolescents.[6,7] Improvements in strength, power, sprint performance, and motor skill performance have been reported to occur following resistance training in adolescents.[6,8] Despite the clear benefits of resistance training, there is a lack of research investigating the effects of different resistance training progression models to improve muscular strength in adolescents, and particularly in adolescent athlete populations.

Previous reviews[9,10] and meta analyses[11] have concluded that periodised resistance training programmes are more effective than

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non-periodised programmes to improve strength and power in adults. Although debate exists in the interpretation of and appropriate terminology to describe periodisation approaches,[12] two commonly investigated models are traditional or linear periodisation (LP) and non-traditional or undulating periodisation (UP). Differences between the models are the manipulation of volume and intensity across a time period. Linear periodisation is characterised by an initial high volume and low intensity of training with progressive increases in intensity and decreases in volume over time.[13] Undulating periodisation features more frequent daily, weekly or bi-weekly variation of intensity and volume.[14] These non-linear manipulations of volume and intensity, providing more frequent changes in stimuli, are suggested to be more conducive to strength gains.[15] Studies, predominantly conducted in recreationally-active adult males, have directly investigated LP and DUP with mixed findings. A recent systematic review found no clear difference between linear and undulating periodised programmes.[16]

Minimal evidence of the effectiveness of periodisation models exists in adolescent populations. One study has reported LP to increase strength significantly after 9-weeks training in untrained adolescents,[17] whereas another study found that DUP resulted in greater percentage improvements in strength than a non-periodised programme.[18] No previous study has directly compared LP and DUP in adolescents. Therefore, the purpose of this study was to determine and compare the effectiveness of two different resistance training progression models, linear and daily undulating, on back squat and bench press performances following 12-week resistance training programmes in sub-elite adolescent rugby union players.

2. Methods

This study was a quasi-experimental trial and was implemented and reported following the Consolidated Standards of Reporting Trials (CONSORT) guidelines for randomised trials. Twenty-six adolescent males (aged 14 to 18 years) were recruited from two representative rugby union squads (16 from Squad 1; 10 from Squad 2). Participants from Squad 1 were randomised to one of two resistance training progression models, LP (16.8 ± 1.0 y) or DUP (17.0 ± 1.1 y) for 12 weeks; participants from Squad 2 formed the non-randomised control group (CON; 15.5 ± 1.0 y) who were not provided the training programme until after the 12 weeks. The study ran during the preseason period prior to the commencement of regular competition games. The LP and DUP groups performed their regular sports training (twice weekly 60-min rugby skill based sessions) in addition to the resistance-training programme. The CON group undertook their regular sports training (twice weekly 60-min rugby skill based sessions) and were asked to refrain from performing any resistance training for the duration of the study. Participants from Squad 1 had participated in twice-weekly resistance training for six months prior to study commencement. This prior training was non-periodised and had a focus on technical execution of resistance training exercises and general strength development. Participants from Squad 2 had little prior resistance training.

A power calculation was conducted to determine the sample size necessary to detect changes in box squat performance. Using an alpha of 0.05 and power of 80%, it was determined that a sample size of 8 per group was required to detect a change of 20 kg (SD = 30 kg). Following baseline assessments, Squad 1 participants were stratified by age and lower body relative strength (estimated box squat 1RM/body weight) and then randomised to the LP and DUP groups using a random number generator by an independent researcher. Participants in Squad 2 were allocated to the CON group.

The primary outcome measures were changes in five-repetition maximum (5RM) box squat and bench press performances. A range of secondary measures was also assessed. Assessments were conducted by trained research assistants, who were blinded to treatment allocation at baseline and 12 weeks. All assessments took place at the University of Newcastle. Ethics approval for this study was obtained from the University of Newcastle Human Research Ethics Committee and all participants provided written informed consent; parental consent was also provided for participants younger than 18 years. The trial was registered with the Australia and New Zealand Clinical Trials registry (ACTRN12612000278831).

Height was recorded using a calibrated stadiometer (Harpenden portable stadiometer with high speed Veeder-Root counter, Holtain Ltd, Pembrokeshire, United Kingdom) and body mass determined using calibrated scales (CH-150kp, A&D Mercury Pty Ltd., Seven Hills, NSW, Australia). Repeated assessments were performed to ensure accuracy of measures. If there was a difference of 0.3 cm or 0.1 kg between the two measurements, a third measure was taken. Body fat percentage and skeletal muscle mass (kilograms) were determined via bio-impedance analysis using the INBODY720 Body Comp analyser (InBody720, Biospace Co., Ltd, Seoul, Korea).

The advancement of biological maturation towards full maturation status was determined using the Tanner staging criteria via self-assessment techniques.[19] The Tanner criteria determine sexual maturation according to five distinct reference stages for the development of secondary sexual characteristics[19] and have shown a very strong relationship ($r = 0.799$) with other maturity indicators.[20] Participants were individually instructed on how to complete the scale. Each participant was provided with Tanner stage diagrams and completed the scale in private by identifying the stage they were currently in, sealed it in an envelope, and handed the envelope to the assessor.

Box squat and bench press five repetition maximum (5RM) tests were used to determine maximal strength. Box squat testing was performed using a barbell and inside a squat rack. Squat depth was individualised to a half squat range of motion and standardised by placing a box behind the lifter, set at the height of the participant's inferior aspect of the patellar. During each repetition, participants were required to eccentrically lower and touch the box before concentrically squatting the barbell. Bench press testing was performed on a standard free weight bench press station. All participants completed a thorough standardised dynamic warm up, which included skipping, body weight lunges and dynamic stretches. Participants were provided with detailed instructions of the required exercise techniques by experienced strength and conditioning coaches. Three to five warm up sets of 5–10 repetitions with an unloaded bar were used to familiarise participants with the exercises. Participants then performed the 5RM tests, gradually increasing the load each set so that a 5RM was obtained from 3 to 5 sets. Three to five minutes rest was provided between attempts. The training groups were also assessed after 6 weeks to assess progress and inform training progressions. Estimated 1RM was determined using Tucker's equation[21] (constant error between predicted and actual 1RM of 0.4 ± 3.0 kg; and ICC 0.93) for predicting 1RM from reps to fatigue ($1RM\ (kg) = 1.139 \times Weight + [0.352 \times reps] + 0.243$.

Participants in the training groups performed two 60-min resistance-training sessions per week for 12 weeks. Each 12-week programme consisted of two 6-week training blocks. An experienced strength and conditioning coach supervised all training sessions. The two training programmes differed only in the manipulation of volume and intensity for the back squat and bench press. All other training variables were the same for both groups. Table 1 describes the volume and intensity patterns of the LP and DUP programmes for the back squat and bench press across each 6-week block.