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Original Investigation

Effects of In-Season Velocity- vs. Percentage-Based Training in Academy Rugby League Players

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ABSTRACT

Purpose: To compare the effects of velocity-based training (VBT) versus percentage-based training (PBT) on strength, speed and jump performance in academy rugby league players during a 7-week in-season mesocycle.

Methods: Twenty-seven rugby league players competing in the Super League U19s Championship were randomised to VBT (n = 12) or PBT (n = 15). Both groups completed a 7-week resistance training intervention (2x/week) that involved the back squat. The PBT group used a fixed load based on a percentage of one repetition maximum (1RM), whereas the VBT group used a modifiable load based on individualised velocity thresholds. Biomechanical and perceptual data were collected during each training session. Back squat 1RM, countermovement jump (CMJ), reactive strength index (RSI), sprint times, and back squat velocity at 40-90% 1RM were assessed pre- and post-training.

Results: The PBT group showed *likely* to *most likely* improvements in 1RM strength and RSI, whereas the VBT group showed *likely* to *very likely* improvements in 1RM strength, CMJ height, and back squat velocity at 40 and 60% 1RM. Sessional velocity and power were *most likely* greater during VBT compared with PBT (standardised mean differences [SMDs] = 1.8 to 2.4), whilst time under tension and perceptual training stress were *likely* lower (SMDs = 0.49 to 0.66). The improvement in back squat velocity at 60% 1RM was *likely* greater following VBT compared with PBT (SMD = 0.50).

Conclusion: VBT can be implemented during the competitive season, instead of traditional PBT, to improve training stimuli, decrease training stress, and promote velocity-specific adaptations.

Keywords: Velocity-based training, load-velocity relationship, training load, competitive season, resistance training.

INTRODUCTION

Resistance training is an integral component of long-term athlete development in rugby league. Regular engagement in resistance training induces marked neurological, musculoskeletal and morphological adaptations that are important for successful rugby league performance.[1,2] However, acute bouts of resistance exercise can lead to considerable neuromuscular fatigue lasing up to 72 hours.[3] This is particularly problematic for rugby league players during the competitive season because excessive fatigue may impair match performance.[4] Therefore, it is important to carefully regulate training load during this period.

The traditional approach to prescribing resistance training load is to use a percentage of one repetition maximum (1RM), known as percentage-based training (PBT). Using this method, the external load is fixed until the 1RM assessment is repeated, usually at the end of a mesocycle. While PBT has been shown to be effective for improving surrogate measures of rugby league performance,[5-7] it is not sensitive to the athlete's daily readiness to train. Maximal strength can fluctuate on a day-to-day basis or change throughout the training block.[8] Consequently, prescribing loads based on percentage 1RM can lead to a suboptimal training stimulus.

The recent development of portable kinematic devices has enabled practitioners to obtain instantaneous measurements of barbell velocity.[9] As a result, velocity-based training (VBT) has become a popular method of regulating resistance training load. VBT is characterised by lifting with maximal intended velocity and adjusting training load based on the resultant velocity data. A decline in barbell velocity is representative of neuromuscular fatigue,[10] whereas greater velocity attained against a given absolute load may indicate enhanced muscle strength.[11] Therefore, VBT can be used to manipulate training load according to the athlete's current physiological state.

Whilst several VBT approaches exist, recent research has encouraged the use of individualised load-velocity relationships.[12-14] This method involves obtaining concentric velocity data across the loading spectrum and establishing velocity thresholds at each relative load, which are then used to modify subsequent training load. Dorrell et al[15] recently reported that six weeks of prescribing training load based on generalised velocity zones led to greater improvements in countermovement jump (CMJ) height than PBT in 16 recreationally-trained men. However, the use of general velocity thresholds does not account for the large inter-individual heterogeneity in load-velocity relationships.[12] In addition, no study has compared VBT to PBT in sportspeople during the competitive season, which is arguably where VBT could have the greatest application. Therefore, the purpose of this study was to compare the effects of VBT versus PBT on strength, speed and jump performance in semi-professional academy rugby league players during the competitive season. Sessional kinematic, kinetic and perceptual data were also compared between-groups.

METHODS

Participants

Academy rugby league players were recruited from one English Super League club during the second half of the competitive season. All players were free from injury, were currently competing in the Super League U19s Championship, and had competed a 12-week pre-season training block prior to entering the study. In addition, all participants had at least two years of resistance training experience as part of a Super League U15-U16s Scholarship squad. Participants were informed of the experimental procedures before giving written informed consent, and parental/guardian consent was obtained for participants aged < 18 years. Ethical approval for the study was granted by the relevant institutional review board in line with the Declaration of Helsinki.

Experimental design

This study used a parallel-group, randomised design. Participants were randomly allocated (1:1) to 7-weeks of either VBT or PBT in block sizes of four using online randomisation software. Both groups completed two resistance training sessions per week that involved the back squat. VBT involved adjusting back squat load using real-time velocity feedback, whereas PBT involved a fixed load based on baseline 1RM. Outcomes of strength, speed and jump performance were assessed at baseline (before randomisation) and post-intervention endpoint. Biomechanical and perceptual data were also collected during each training session.

Procedures

Participants completed performance testing on three separate days, with 24-48 hours recovery between each day. Day 1 involved a CMJ, a drop jump (DJ) and a 30 m linear sprint. Day 2 involved a 1RM test, and day 3 involved an assessment of load-velocity relationships. In the following training week, participants were randomly assigned to PBT or VBT and began the 7-week training mesocycle. After the completion of the final resistance training session, testing for outcome measures was repeated in the next training week.

Outcome measures

One repetition maximum

Participants completed 1RM testing in the free-weight back squat using methods described previously.[9] Briefly, participants performed a standardised warm-up followed by five repetitions at ~50% 1RM, three repetitions at ~70% 1RM, and two repetitions at ~80% 1RM. Thereafter, participants performed 1RM attempts with progressively increased loads. Participants were required to achieve a parallel squat depth (thigh parallel to the floor), which was monitored by a member of the research team. A maximum of five attempts were permitted and the last successful lift was taken as the 1RM.

Individualised load-velocity relationships

A linear position transducer (GymAware PowerTool [GYM], Kinetic Performance Technologies, Canberra, Australia) was used to measure mean velocity (MV) in the free-weight back squat. Following the same standardised warm-up performed in the 1RM assessment, participants completed three repetitions at 40%, three repetitions at 60%, two repetitions at 80%, and one repetition at 90% of baseline 1RM. GYM has been shown to obtain reliable measurements of MV at 40-90% 1RM.[9] Participants were verbally encouraged to complete each repetition with maximal concentric velocity, although objective velocity feedback was not provided. Three minutes of rest was provided between each relative load. Individualised load-velocity relationships were constructed by plotting MV against load and applying a line of best fit.[13] The MVs corresponding to 60 and 80% 1RM were used to modify training load in the VBT group. At post-intervention, load-velocity relationships were constructed with the same absolute loads used in the baseline assessment.

Sprint performance

Following a dynamic warm-up and one practise 30 m sprint, participants completed two maximal 30 m sprints, with times being recorded at 5, 10, 20 and 30 m intervals using a photocell timing system (Witty Timing System, Microgate, Balzano, Italy). Three minutes rest was provided between efforts. Reliability for each sprint distance was high (coefficient of variations = 2.0 to 4.5%). All sprints took place on the same outdoor 4G artificial turf and began from a standing start. The fastest sprint was used for analysis.

Jump performance

CMJ and DJ tests were administered indoors using the Optojump photocell system (Optojump, Microgate, Bolzano, Italy), which samples at 1000 Hz and consists of two dual-beam bars (100 x 4 x 3 cm) that were placed in parallel approximately 1 m apart.[16] For the CMJ, participants placed their hands on their hips and descended downwards to a self-selected level before jumping upwards for maximum height. For the DJ test, participants stepped off a standardised box (height, 30 cm) with their preferred leg, landed on the floor with both feet, and immediately jumped as high as possible. Participants received instructions to maintain their hands on their hips, to keep their legs as straight as possible on contact with the ground, and to minimise ground contact time. Three CMJS and DJs were performed with the highest jump (cm) and reactive strength index (RSI = jump height [m] / contact time [s]) used for analysis, respectively. Sixty seconds of rest was provided between each jump. Coefficient of variations for CMJ height and RSI were 2.7% and 8.0%, respectively.

Exercise responses

Participants completed a perceived wellness questionnaire prior to every resistance training session. The questionnaire included five items (muscle soreness, fatigue, stress, sleep and mood) on a 7-point Likert scale ranging 'very bad' to 'great'. Higher scores indicated better perceived wellness. RPE data were collected after the completion of every set using the OMNI-RES scale.[17] All participants were familiarised with the OMNI-RES during prior training sessions and the scale was always in full view. MV, mean power (MP), TUT, work and barbell load of each back squat repetition were also recorded.

Training routine

Resistance training sessions were completed on a morning (7 a.m.), with field sessions (rugby league skills and conditioning) taking place in the afternoon of the same day (16:30 p.m.). An additional low-intensity field session ('team run') was performed 24 hours before a competitive match. Furthermore, participants completed a training session that focused on active recovery and general motor ability approximately 48 hours after a match (Figure 1). Each resistance training session began with a standardised warm-up followed by four sets of five free-weight back squat repetitions, separated by 2-3 min inter-set rest periods. The PBT group performed back squats with a fixed load based on their baseline 1RM, whereas the VBT group performed back squats with a modifiable load based on a target velocity threshold established from individualised load-velocity relationships. Both groups received the same encouragement to lift with maximal intended concentric velocity and complete the eccentric phase in a controlled manner, although neither group received instantaneous velocity information to control for the effect of feedback.[18] Following back squats, participants then completed the same four supplementary exercises (Nordic lower/Romanian deadlift, upper-body push, upper-body pull, anti-extension) using body weight or a repetitions in reserve approach to adjust load (Table 1).

Percentage-based training

In the first weekly session, the PBT group performed back squats with 80% of baseline 1RM, while the second weekly session was performed with 60% 1RM. These loads were chosen because they are regularly prescribed in strength programmes, they target distinct physical qualities on the strength-velocity continuum, and velocity data attained at these loads are reliable.[9] The barbell load was not adjusted during the 7-week mesocycle.

Velocity-based training

Participants in the VBT group performed one weekly session with a load that corresponded to MV at 80% 1RM established from their individual load-velocity relationship. The second weekly session was completed with a load corresponding to MV at 60% 1RM. The load for the first set of session one and the first set of session two were 80% and 60% 1RM, respectively. Thereafter, if the maximum MV in a set of five repetitions was ± 0.06 $m \cdot s^{-1}$ outside of the target movement velocity, the barbell load was then adjusted by ± 5% 1RM for the subsequent set. A threshold of ± 0.06 $m \cdot s^{-1}$ was chosen based on the measurement error in MV obtained by GYM[9] and to align with previous research.[13] Training load was modified based on the maximum MV in a set (rather than mean MV) because load-velocity relationships were constructed with the maximum value.

Data analysis

Exercise responses to back squats at 60% 1RM were analysed separately to responses at 80% 1RM. All biomechanical data were collected during the concentric phase. The placement of GYM and the methods used to calculate MV and MP have been described previously.[9,19,20] Work was determined as the area underneath the force-displacement curve during the concentric phase of each repetition, and TUT represented the time spent during the same period. Data obtained from GYM were transmitted via Bluetooth to a tablet (iPad, Apple Inc., California, USA) using the GymAware v2.1.1 app and uploaded onto a cloud-based system. Body mass and barbell load were entered into the app prior to each set. MV, TUT, work and barbell load were determined as the average of all repetitions for each individual across the training intervention. Perceived wellness and RPE were also determined as the average of all data collected during the intervention to reduce the number of statistical comparisons made.

Statistical analysis

Data were analysed using Microsoft Excel spreadsheets.[21] Participants were required to attend ≥ 70% of resistance training sessions to be included in the analyses. A magnitude-based inference (MBI) approach was used to assess the magnitude of effects within- and between-groups, which interprets the mean differences and their corresponding 90% confidence intervals (CIs) in relation to the smallest worthwhile change (SWC).[22] The SWC was considered to be 0.2 times the standard deviation (SD) at baseline.[23] Standardised mean differences (SMDs) from pre to post-intervention were calculated using the formula: (mean change/baseline SD), which was divided by (1-3/(4df-1)) to adjust for a small sample size. Values of < 0.2, 0.2 to 0.59, 0.6 to 1.19, and 1.2 to 2.0 were considered trivial, small, moderate, and large effects, respectively.[24] SMDs in change scores, sessional MV, MP and barbell load were compared between-groups using baseline values as covariates. Covariates were not used to compare RPE, TUT, work nor perceived wellness. Effects that favoured VBT are reported as positive SMDs, whereas effects that favoured PBT are reported as negative SMDs. The qualitative probabilities that the magnitude of effect was greater than the SWC was rated as: < 0.5%, *most unlikely*; < 5%; *very unlikely*; < 25%, *unlikely*; 25-75%, *possibly*; > 75%, *likely*; > 95%, *very likely*; > 99.5%; *most likely*.[21] Data are presented as mean ± SD or SMD ± 90% CI.

RESULTS

Thirty-two players were initially recruited, although five withdrew due to leaving the club (n = 3) or suffering an injury during a competitive match (n = 2). Therefore, 27 participants completed the intervention (Table 2). Compliance was 86% in the PBT group and 90% in the VBT group.

Exercise responses

Relative to the 60 and 80% 1RM sessions in the PBT group, average loads in the VBT group were 62 and 79% 1RM, respectively. Sessional MV and MP were *most likely* greater during VBT compared with PBT (Figure 2), whilst TUT and perceived training stress were *likely* lower (Figure 3). Compared to the PBT group, VBT elicited *likely* higher RPE at 60% 1RM, but *likely* lower RPE at 80% 1RM (Figure 2).

Performance outcomes

The PBT group showed *likely* to *most likely* improvements in 1RM strength and RSI, whereas the VBT group showed *likely* to *very likely* improvements in 1RM strength, CMJ height, and back squat MV at 40 and 60% 1RM (Table 3). The improvement in back squat MV at 60% 1RM was *likely* greater following VBT compared with PBT (SMD = 0.50). Both groups showed reductions in sprint performance (Table 3), although the change in 10 m sprint time *possibly* favoured the PBT group (SMD = -0.21 ± 0.40). All other SMDs in change scores between-groups were *likely trivial* or *unclear* (Figure 4).

DISCUSSION

The main finding was that VBT promoted greater sessional MV and MP compared with conventional PBT, whilst TUT and perceived stress were lower. The improvement in back squat velocity attained against 60% 1RM was also greater following VBT compared with PBT. Therefore, VBT could be implemented during the competitive season to increase back squat repetition velocity, minimise lower-body mechanical stress, and promote velocity-specific adaptations.

Sessional MV and MP were *most likely* greater during back squats in the VBT group compared with PBT group (SMDs: 1.8 to 2.4). In addition, concentric TUT and perceived training stress were *likely* reduced in the VBT group, whilst differences in concentric work were *unclear*. This finding agrees with previous research showing that, at the cross-sectional level, prescribing training load based on individualised load-velocity profiles yielded greater MV (SMD = 1.05), similar total work, and less TUT compared with PBT during five sets of five back squats.[13] Others have also shown that limiting velocity loss during a set leads to higher MV during 6-8 weeks of back squat training in resistance-trained males[25] and professional soccer players.[26] Hence, our findings extend those of previous studies by showing that VBT enhances lower-body training stimuli whilst minimising training stress during a competitive rugby league mesocycle.

The improvement in back squat velocity at 60% 1RM was *likely* greater following VBT compared with PBT (SMD = 0.50). The uncertainty of the SMD (90% CI: -0.16 to 1.16) shows that differences compatible with the data range from a trivial effect to a moderate effect favouring VBT. Hence, adjusting training load based on velocity feedback, rather than a percentage of 1RM, has negligible negative effects but potentially moderate benefits on back squat velocity at 60% 1RM. This favourable shift in the load-velocity relationship ostensibly resulted from the higher training velocities elicited by VBT and represents an improvement in explosive strength. Explosive strength is the ability to maximise force in minimal time, and is often a key objective of strength and conditioning programmes because many rugby league actions require force to be applied quickly. However, it is unknown whether this adaptation is exclusive to the back squat or whether it could also transfer to enhanced rugby league match-play.

Both groups comparatively improved 1RM strength. In addition, although the difference in CMJ height favoured VBT (0.28 ± 0.61), the effect estimate was small and the precision of the estimate was low, leading to an *unclear* difference between groups. Thus, VBT did not provide additional benefit over PBT for these outcomes, which can be explained by training specificity. Back squats at 60 and 80% 1RM are performed at moderate to slow velocities, respectively, and training with these loads will produce the greatest gains in strength at moderate to slow velocities.[27] As a result, the higher sessional MV elicited by VBT at 60 and 80% 1RM is unlikely to lead to further improvements in 1RM strength or jumping performance, which represent two extremes of the load-velocity continuum. These results suggest that either PBT or VBT can be utilised when maximal lower-body strength or explosive jump performance is the primary training objective.

Sprint performance decreased in both groups, which may have been because the 7-week mesocycle did not include any linear sprint training nor horizontally-loaded resistance exercises. Previous research has shown that sprint performance does not improve during a rugby league season despite regular speed training.[28]. Sprint times have also been shown to worsen in international rugby union forwards during the second half of the competitive season, which was attributed to accumulated match fatigue.[29] Thus, a lack of specific training could have combined with residual fatigue to impair sprint performance. Surprisingly, the change score in 10 m sprint time *possibly* favoured PBT (SMD = -0.21 ± 0.40). However, this finding was presumably due to chance variation and/or noise given the 90% CI touched the upper boundary of the SWC and the direction of SMDs in 5, 20 and 30 m sprint times actually favoured the VBT group (Figure 4).

An interesting finding was that VBT elicited *likely* higher RPE at 60% 1RM (SMD: 0.65), but *likely* lower RPE at 80% 1RM (SMD: -0.67). The higher RPE at 60% 1RM may be related to *possibly* greater barbell load (SMD: 0.35) given the direct relation between RPE and load,[30] although unclear differences were found in concentric work. Relative to the 60 and 80% 1RM sessions in the PBT group, the average loads in the VBT group were 62 and 79% 1RM, respectively. Hence, players in the VBT group increased sessional MV more when lifting 60% 1RM than 80% 1RM, which led to barbell load being increased across the mesocycle. This is supported by the finding that adaptations in the load-velocity relationship induced by VBT were specific to 60% 1RM. Consequently, using VBT methods at 60% 1RM may lead to greater loads and RPE compared with PBT, whilst VBT at 80% 1RM appears to maintain barbell load but reduce RPE.

There are some limitations to this study. Training load was only manipulated in the back squat, however, this aligns with previous VBT papers[25,26] and using velocity thresholds to adjust load in other lower-body exercises included in the training routine (Nordic lowers/unilateral Romanian deadlift) was not appropriate because maximising concentric velocity is not the main training objective for these exercises. Another limitation is that training load was not adjusted in the PBT group, whilst the VBT group continually modified load. Furthermore, although participants were randomised and completed the same training regimen, it cannot be guaranteed that on-field player loads were the same between groups, which could have influenced training adaptations. Finally, the magnitudes of effects were interpreted in relation to the SWC (baseline SD x 0.2). Whilst this distribution-based statistic is widely used throughout the literature, it does not consider whether the magnitude of effect is important for rugby league performance.

PRACTICAL APPLICATIONS

This study suggests that adjusting resistance training load based on individual velocity thresholds is a superior alternative to conventional percentage-based approaches during the competitive rugby league season. VBT promoted faster back squat repetition velocities, minimised mechanical stress, and improved lower-limb explosive strength. However, it should be considered that VBT requires the use of relatively expensive devices, additional time to set up equipment and potentially more staff to competently monitor sessional velocity. Coaching staff must judge whether the benefits of VBT outweigh the increased financial and time burden compared with PBT.

CONCLUSIONS

VBT was associated with greater sessional velocity and power, as well as lower TUT and perceived training stress, throughout a 7-week mesocycle compared with PBT. VBT also led to a greater improvement in back squat velocity attained against 60% 1RM compared with PBT. Therefore, this study is the first to show that VBT can be implemented during the competitive rugby league season, instead of traditional PBT, to improve lower-body training stimuli, decrease unnecessary training stress, and promote velocity-specific adaptations.

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Table and Figure captions

Table 1. Summary of resistance training sessions during the 7-week mesocycle

Table 2. Baseline characteristics (mean ± SD)

Table 3. Mean ± SD at pre- and post-intervention, within-group change scores in standardised units (Δ SMD ± 90% CI) and qualitative inferences

Figure 1. Weekly in-season training schedule during the 7-week mesocycle. GMA = general motor ability; RT = resistance training.

Figure 2. Sessional mean velocity (MV, panel A), mean power (MP, panel B), time under tension (TUT, panel C), work (panel D), barbell load (BL, panel E), and rating of perceived exertion (RPE, panel F) at 60% and 80% of one repetition maximum (1RM) in percentage-based training (PBT) and velocity-based training (VBT) groups. Data are presented as mean ± SD (TUT, work, RPE) or adjusted mean ± SEE (MV, MP and BL), along with standardised mean differences (SMDs) and the corresponding 90% confidence interval.

Figure 3. Mean perceived wellness scores in percentage-based training (PBT) and velocity-based training (VBT) groups. * VBT had a *likely* beneficial effect on perceived stress (standardised mean difference = 0.66 ± 0.66). All other differences between groups were *unclear*. Data are presented as mean ± SD.

Figure 4. Standardised mean differences (SMDs) between change scores and their corresponding 90% confidence intervals. Area shaded in grey represents a trivial SMD. 1RM = one repetition maximum; PBT = percentage-based training; CMJ = countermovement jump; MV = mean velocity; RSI = reactive strength index; VBT = velocity-based training.