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EFFECTS OF TWO PLYOMETRIC TRAINING PROGRAMMES OF DIFFERENT INTENSITY ON VERTICAL JUMP PERFORMANCE IN HIGH SCHOOL ATHLETES

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Abstract Although plyometric training is a significant component of most conditioning programme designs, little research exists with regards to the design/structure of specific plyometric training interventions and the intensity involved. The aim of this study was to compare the effect of intensity manipulation on a 6-week plyometric training programmes on vertical jump performance. Eighteen healthy adolescent male subjects were randomly allocated to a periodised plyometric intensity (INCR), a constant moderate plyometric intensity (CONS) and a control (CONT) group, for a 6-week plyometric training programme. Pre- and post-training measurements of net impulse, vertical take-off velocity, jump height and peak force were calculated from a countermovement jump. Contact time and flight time, rebound height and reactive strength index were calculated from a drop jump. INCR and CONS groups achieved improved vertical jump performance compared to CONT ($P < 0.05$). Although there were no significant differences ($P > 0.05$) between CONS and INCR for any of the performance variables, there was a trend for greater improvement for the INCR group. In conclusion, manipulation of exercise intensity for short duration plyometric training could be less significant than the intervention itself. Longer training durations and density as well as consideration of specific plyometric exercises merit further investigation.

Key words: countermovement jumps, drop jumps, periodisation, young athletes

INTRODUCTION

Plyometric training has been established as a training method that improves the muscle-tendon unit's ability to tolerate stretch loads and the efficiency of the stretch-shorten cycle (SSC) [2, 11]. The positive effects of plyometric training on vertical jump performance are well documented [1, 15, 19, 22] and are generally attributed to both mechanical [8, 16] and neurophysiological [9, 14] adaptations, affecting the efficiency of the SSC [21, 32, 36].

Less consensus exists on the use of traditional training factors and their interaction, such as programme duration, frequency, recovery time, volume and intensity [15]. Training programme durations and frequencies vary considerably [27], longer resting intervals may have been unnecessary [31], volume is usually defined as foot contacts or time spent performing the exercise, while intensity is usually based on practical recommendations or anecdotal recommendations [24]. In addition, when drop jumps are included in the programme, the drop height becomes an additional factor [26, 38].

To design successful plyometric training programmes, it is important that the effects of these variables are better understood [15]. Intensity, in particular, impacts on plyometric training in two ways. On one hand, it is a crucial programme design parameter, as SSC is primarily based on fast, explosive movements that fully utilise the elastic recoil of the muscle-tendon unit [8, 21]. On the other hand, the intensity involved in plyometrics places significant stress on the musculoskeletal system [18]. It is crucial,

therefore, to examine whether intensity manipulation in short term plyometric programmes elicits additional benefits or the athletes are unnecessarily subjected to higher musculoskeletal stresses and increased injury likelihood.

Unfortunately, although the intensity has been altered in experimental groups of previous studies during intervention, a constant intensity group has not been used [9, 15, 33]. This did not allow for a clear indication of whether intensity manipulation was indeed necessary. The purpose of the present study was to compare two different plyometric training programmes of six-weeks' duration, by increasing the intensity on one group while maintaining it constant on the other. It was hypothesized that intensity manipulation would improve countermovement jump and drop jump performances further compared to a constant intensity programme.

MATERIALS AND METHODS

SUBJECTS

Eighteen adolescent males (mean \pm SD: age 14.5 ± 0.5 years, height 1.74 ± 0.07 m, body mass 65.2 ± 9.26 kg), actively competing in English Rugby League, participated in the current study. The study was approved by the Department's Ethics Committee and the subjects and their parents provided written, informed consent.

BATTERY OF STABILISATION STRENGTH TESTS

All subjects were required to complete a battery of stabilisation strength tests to evaluate their ability to complete a plyometric training programme. These tests comprised of a static stand (hip flexed), hop for distance, hop down (from a 0.4 m platform), repetitive jump test, single leg and 1.5 times body weight squat [19, 30]. Form and technique were observed throughout and used to identify the completion of the tests. All subjects completed the battery of stabilisation strength tests successfully.

PROCEDURES

The subjects were randomly assigned to one of three groups; control (CONT; $n=6$), constant intensity plyometric training programme (CONS; $n=6$), and manipulated (increasing) intensity plyometric training programme (INCR; $n=6$). CONS and INCR groups performed a plyometric training programme two times per week for 6 weeks (see *Plyometric training protocols*). One session was performed in a gymnasium (hard surface) and the other on grass (soft surface), as the subjects were still involved in mid-season obligations. All subjects continued with their normal rugby training and games.

PLYOMETRIC TRAINING PROTOCOL

CONS completed a non-varied plyometrics training programme, while INCR completed a varied plyometrics training programme. More specifically, INCR performed each combination of high-volume / low-intensity, moderate-volume / moderate-intensity and low-volume / high-intensity plyometrics for two weeks. Both programmes were equal in terms of work volume (total foot contacts). The specific details of the training protocols are outlined in Table 1. CONT attended their normal training sessions and was not involved in any additional plyometric training.

MEASUREMENTS

Sum of four skinfolds (SUM4SF) was calculated from measurements at biceps, triceps, subscapular and suprailiac sites using skinfold calipers (Harpندن, UK), both at pre- and post-training. The measurement was taken to examine any changes in body fat content between testing points.

Countermovement jumps (CMJ) were used to provide a measure of slow reactive strength, while drop jumps (DJ), performed from a height of 0.4 m [6], were used to provide an indication of fast reactive strength [32]. To isolate the contribution from the leg muscles, subjects placed their hands on their hips throughout each jump for both CMJ and DJ [5, 7, 16, 20]. In addition, when performing the DJ, subjects were instructed to 'step off' rather than jump off the platform, to ensure a consistent drop height. All subjects were allowed sufficient familiarisation with the jump tests.

Jump performance variables were measured on a Bertec force platform (Columbus, OH) with an analogue-to-digital converter interfaced to a desktop computer, relaying information via the Provec v5.0 software (Leeds, United Kingdom). The force data was sampled at 200 Hz for 6 seconds. Net impulse, vertical take-off velocity, and jump height were calculated from the CMJ force-time curve, using the net impulse method [25, 35]. The force-time curve integration was started 0.5 seconds before the jumping

movement. The averaging period for body weight was set at 1 second and the start of take-off was determined when the force level reached 1 N [35]. Peak vertical ground reaction force (VGRF) was also recorded.

For the DJ, contact and flight times (s) were determined from the vertical force-time curve. Ground contact and take-off were determined when the force level reached 1 N. DJ rebound height (m) was calculated using the flight time method [25]. Reactivity strength index for the drop jumps was calculated by dividing the rebound height by the contact time [39].

A standardised 10-minute warm-up consisting of light jogging, lower limb muscle stretching and some practice jumps was performed before all testing. Sufficient rest was allowed following the warm-up. All measurements were taken at the same time and day of the respective week, to control for circadian variation [4].

STATISTICAL ANALYSIS

SUM4SF pairwise comparisons were conducted between pre- and post-training for each group. All jump performance variables were analysed with a 3 (Group; CONT, CONS, INCR) × 2 (testing points; pre-training, post-training) factorial analysis of variance (ANOVA). Pairwise comparisons with Bonferroni adjustment were conducted if significant main effects had been found. Finally, percentage differences of the variables were calculated and a one-way ANOVA was conducted. All statistical analyses were conducted using SPSSv14 (Chicago, Illinois). Significance was set at $P < 0.05$.

RESULTS

Data were examined to verify that they met the assumptions for analysis of variance [17]. SUM4SF did not show any significant difference for any of the groups (CONT: $t = -0.616$, $df = 5$, $p = 0.565$; CONS: $t = 0.248$, $df = 5$, $p = 0.814$; INCR: $t = -0.686$, $df = 5$, $p = 0.523$) indicating similar body fat content between pre- (CONT, $33.6 \pm 6.8\text{mm}$; CONS, $42.5 \pm 14.1\text{mm}$; INCR, $43.0 \pm 11.0\text{mm}$) and post-training (CONT, $34.0 \pm 7.0\text{mm}$; CONS, $42.2 \pm 13.0\text{mm}$; INCR, $43.7 \pm 11.9\text{mm}$). Mean and standard deviation values for jump performance variables are presented in Tables 2 and 3 (for CMJ and DJ, respectively).

Table1. The training protocols for the increasing and constant intensity plyometric training groups. The exercises are prescribed as sets x foot contacts. The platforms used in all plyometric drills were 0.4 m in height [6]

Weeks	CONS	INCR
1 & 2	Tuck jumps (2 x 10) Alternate leg bounds (2 x 10) Two-footed bench hops (2 x 15) Rim Jumps (2 x 20) (60 – 90 s recoveries between sets)	Ankle Hops (2 x 15) Alternate leg push offs (2 x 25) Standing vertical jumps (2 x 20) Squat Jumps (2x 10) (30 – 60 s recoveries between sets)
3 & 4	Tuck jumps (2 x 10) Alternate leg bounds (2 x 10) Two-footed bench hops (2 x 15) Rim Jumps (2 x 20) (60 – 90 s recoveries between sets)	Tuck jumps (2 x 10) Alternate leg bounds (2 x 10) Two-footed bench hops (2 x 15) Rim Jumps (2 x 20) (60 – 90 s recoveries between sets)
5 & 6	Tuck jumps (2 x 10) Alternate leg bounds (2 x 10) Two-footed bench hops (2 x 15) Rim Jumps (2 x 20) (60 – 90 s recoveries between sets)	Bench Depth Jumps (2 x 10) Box to box jumps (2 x 10) Single leg vertical jumps (2 x 10) Box to box squat jumps (2 x 10) (5 – 10 s between reps / 120 – 180 s between sets)

Significant pre- and post-training differences were only found for contact time and reactivity index for the INCR group (Table 3). No significant pre- and post-training differences were found for any other performance variables for either group (Tables 2 and 3). Similarly, no significant differences were found when the % differences between groups were compared for both CMJ (Figure 1) and DJ (Figure 2).

Notably, there is a trend with the CMJ performance indicators (impulse, jump height, take-off velocity) and the DJ performance indicators for greater improvements following the INCR programme compared to CONS (Tables 2 and 3).

Table 2. CMJ performance variable values pre- and post-training for the 3 groups. Data are presented in mean (SD)

Variable	CONT		CONS		INCR	
	Pre	Post	Pre	Post	Pre	Post
Net Impulse (N·s)	143.7 (28.28)	143.47 (26.36)	143.82 (25.37)	150.21 (27.84)	146.51 (19.99)	159.93 (25.96)
Jump Height (m)	0.26 (0.03)	0.25 (0.02)	0.25 (0.03)	0.27 (0.04)	0.24 (0.04)	0.28 (0.07)
Take off Velocity (m/s)	2.28 (0.13)	2.21 (0.07)	2.22 (0.14)	2.29 (0.17)	2.16 (0.17)	2.32 (0.3)
Peak VGRF (N)	1319.43 (265.75)	1410.26 (325.52)	1552.68 (264.11)	1555.17 (131.37)	1649.21 (320.04)	1433.14 (188.31)

Table 3. DJ performance variable values pre-and post-training for the 3 groups. Data are presented in mean (SD)

Variable	CON		CONSTANT		INCREASED	
	Pre	Post	Pre	Post	Pre	Post
Rebound Height (m)	0.27 (0.04)	0.24 (0.04)	0.25 (0.07)	0.25 (0.08)	0.24 (0.02)	0.26 (0.03)
Flight Time (s)	0.47 (0.03)	0.44 (0.03)	0.45 (0.06)	0.45 (0.06)	0.44 (0.02)	0.46 (0.02)
Contact Time (s)	0.53 (0.11)	0.42 (0.12)	0.31 (0.04)	0.26 (0.08)	0.36 (0.09)	0.26* (0.03)
Reactivity Index (cm/s)	53.58 (15.52)	59.4 (12.76)	80.58 (24.07)	100.48 (26.16)	70.25 (23.12)	98.65* (15.23)

* indicates significant difference ($P < 0.05$) between pre- and post-training.

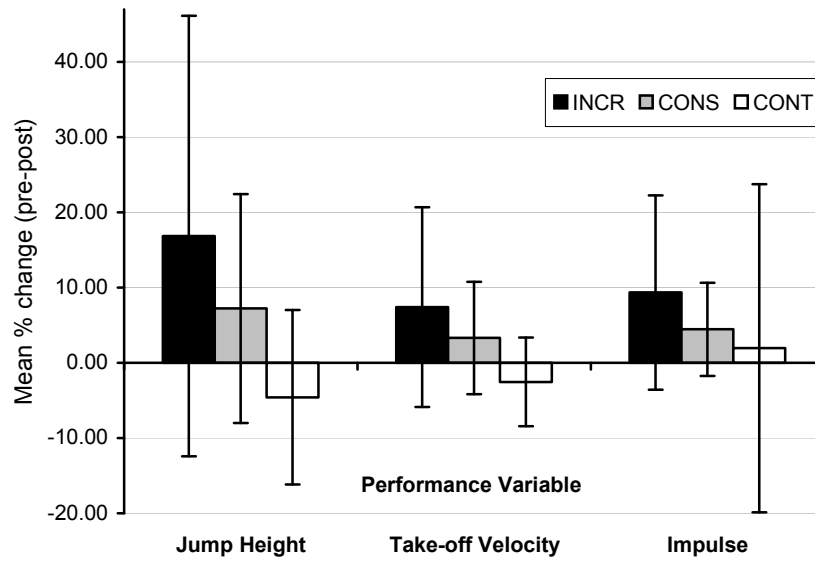


Figure 1. Mean percentage changes in CMJ performance variables following each training programme. Vertical bars denote SD (INCR denotes Increased Intensity group, CONS denotes Constant intensity group and CONT denotes Control group)

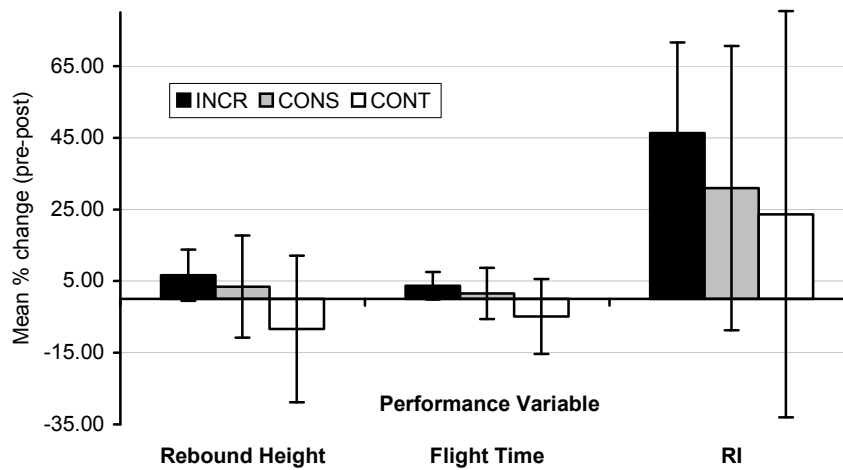


Figure 2. Mean percentage changes in DJ performance variables following each training protocol. Vertical bars denote SD (INCR denotes Increased Intensity group, CONS denotes Constant Intensity group and CONT denotes Control group).

DISCUSSION

The aim of the current study was to compare the effect of intensity manipulation on a 6-week, 2 sessions per week plyometric training programme. The results showed no significant benefit of increasing intensity compared to maintaining it constant, hence rejecting our hypothesis.

The current study utilised a 6-week programme duration, with two sessions per week (twelve sessions in total) and found that both plyometric training programmes elicited an increase in CMJ and DJ performances. These results concur with previous studies (utilising training durations between 4 to 24 weeks and various session frequencies), which found plyometric training to improve vertical jump performance [27]. In particular, in an identical duration and frequency training programme to the present study, Chimera et al [9] reported increases in vertical jump performance of female athletes. Fowler et al [18] utilised an even shorter training period of three weeks but with higher frequency, totalling the same overall number of sessions as Chimera et al [9] and the present study, and reported an increase in the height jumped. Finally, Spurrs et al [33] reported increases in CMJ height after a 6-week plyometric training programme (but totalling 15 sessions). Our findings provide further support to the notion that plyometric training can demonstrate benefits in a short period of time, indicating that twelve sessions of plyometric training suffice for initial improvements. Similar to the above studies, the subjects of the current study were well-trained, competitive athletes rather than untrained individuals, highlighting further the effectiveness of plyometric training in improving the explosive power of the lower limbs.

Plyometric exercises can generate high impact forces, increasing the likelihood of, or leading to, injuries [18]. Attempts have been made to examine the impact of surfaces of different hardness [3, 13, 23, 34] on the performance of plyometric exercises. As softer surfaces require lower intensities to be negotiated, performance maintenance on these surfaces would be an important factor in training programme design. It was found that softer surfaces favour vertical jump performances [3, 23] while they prevent the high impact forces normally generated by DJ without increase in contact time [28]. The current study adds to these attempts to minimise the injury likelihood of plyometric exercises by proposing that increasing the plyometric intensity in a short duration training programme is not necessary and that similar performance benefits are generated with moderate plyometric exercise intensity. It is postulated that any mechanical (e.g. lower extremity kinematics or tendon stiffness changes) or neurophysiological (e.g. muscle activation strategies or patterns) adaptations that have taken place, were stimulated equally by the two training programmes.

However, caution needs to be exercised in the interpretation of the findings of the present study. Despite no statistically significant differences found, there was a trend for higher results on all jump performance variables for INCR compared to CONS (Figures 1 and 2). Previous research into the effects of plyometric training in preadolescent athletes has found significantly positive effects [12]. Although longer in duration (10 weeks) and with greater density (three times per week), the authors reported a 12% increase in CMJ height, which is comparable to the 16.86% increase found in the present study. In addition, in a meta-analysis of plyometric training, Markovic et al [27] conclude that plyometric training can produce statistically significant increases of 4.7% for the DJ and 8.7% for the CMJ. Such a percentage increase could represent an improvement of 2-6 cm [27]; quite a worthwhile improvement for many athletes. The question that arises is whether the trend found in this study is a true improvement and what its reasons may be.

The answer could be found in the selection of the exercises. The programme was designed using what traditionally have been high- and low-intensity plyometric exercises in the strength and conditioning field [10, 11, 33]. The aim was to increase intensity as the INCR group progressed through their training programme. However, recent evidence [24] suggests that exercises that were typically used as 'high' intensity may not yield higher motor recruitment compared to lower intensity exercises. As the exercises used for the INCR group may have not been substantially different to CONS, it is possible that the difference in intensity was less than expected, which could in turn explain the trend seen in our results. Jensen and Ebben [24] suggested the eccentric rate of force development to quantify between plyometric exercise intensity; however, the methodology used was time-consuming and unpractical for most coaches and, therefore, unlikely to be used in these settings. Nonetheless, future studies comparing the effects of intensity or plyometric activity should consider the exercise selection carefully, in light of Jensen and Ebben's [24] findings.

Finally, although the sample of 6 subjects per group used in the present study may appear small, previous similar studies have used this sample size for comparisons [13, 24] or interventions [29, 37, 40]. In addition, the sample size is sufficient to identify the true effect, as it was likely that the effect would be remarkable enough.

PRACTICAL APPLICATION

The results of the present study suggest that a short period of plyometric training (two sessions per week for up to 6 weeks) can enhance explosive power and reactive strength ability in young adolescent sports participants. However, the manipulation of intensity of exercises in programme design seems to be less significant than the intervention itself. If this is the case it may be possible to reduce the stress on the muscle-tendon unit caused by high intensity plyometric exercises while achieving the same mechanical and neurophysiological conditioning benefits. Consideration of specific plyometric exercises for optimal explosive power and reactive strength adaptation needs to be made in future research. It is possible that the trend observed in the present study for the benefits of utilising the volume-intensity interaction may become significant with extending programme duration as well as having optimal exercises be training duration-specific. Further research is required to confirm whether the regular practice of periodising plyometric training is more advantageous than non-periodising. Studies of longer duration may be required that will include senior athletes, a greater frequency of training (3 times per week) as well as intensity manipulation.

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