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The Effect of Two Different Assisted Plyometric Programmes on Vertical Jumping Kinetics in Young Male Football Players

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Abstract: *Assisted jumping is documented to improve lower body power, however no current research evaluates it from a skill development standpoint, with limited data evaluating assisted plyometrics. 15 youth football players were separated into a band assisted (BAP) (n = 8) or ground-based plyometrics (GBP) (n = 7) group. Both groups followed similar 6-week plyometric interventions. BAP used resistance bands to increase flight time during all jumps, while GBP performed bodyweight jumps. Participants completed countermovement jumps (CMJ), drop jumps (DJ) and a submaximal hopping (SH) test pre- and post-intervention. Both groups significantly improved jump height and relative peak power in the CMJ (p < 0.05). Neither groups significantly improved reactive strength index (RSI) in the DJ or SH tests, however GBP had a significantly greater mean RSI compared to BAP in the post-test (p < 0.05). Overall, these data demonstrate that band assisted jump training (using a directly transferable assistance method) is effective at improving some vertical jumping kinetics. However, conflicting factors related to mechanical loading, biological maturity and the selected band assistance, limit definitive conclusions. Future research should consider replicating the current study and explore the reasons for the lack of difference between assisted and unassisted conditions.*

Key words: *Team sport, Jumping, Plyometrics, Technique, Cuing.*

Abbreviations: *Jump Height (JH), Power Output (PO), Reactive Strength Index (RSI), Flight Time (FT), Body Mass Unloading (BMU), Drop Jump (DJ), Countermovement Jump (CMJ), Submaximal Hopping (SH), Band Assisted Plyometrics Group (BAP), Ground Based Plyometrics Group (GBP), Arbitrary Units (AU), Physical Activity Readiness Questionnaire (PAR-Q), Romanian Deadlift (RDL), Peak Power Output (PPO), Ground Contact Time (GCT), Participant (PP), Co-efficient of variation (CV), Red Band (R), Orange Band (O), Standard Deviation (SD), Mean (□), Confidence Interval (CI), Mean Difference (MD), Effect Size (ES), Relative Peak Power Output (RPPO)*

1. Introduction

Team sport is a fast paced, dynamic environment that requires both high levels of technical skill and finely tuned physical qualities [1]. While skill level undoubtedly distinguishes between high and low level professional athletes[2-4], improved physical qualities, especially at a young age, can sometimes predict transfer into professional levels and success thereafter[5, 6]. Physical qualities often observed in elite team sport athletes include; the ability to run fast, jump high and an ability to absorb and re-express force quickly in different directions[1, 7, 8]. Excellence in any of these can be linked to game defining moments such as out jumping an opponent to catch a touchdown in American football or cutting forcefully to outsmart a defender in rugby. Moreover, straight sprinting has been shown to be the most frequent action in the lead up to a goal in soccer [9].

Interestingly, all of these game changing movements are underpinned by an athlete's ability to express explosive power [10, 11]. Explosive power is a highly trainable characteristic and can be improved via a number of methods, including; heavy strength, ballistic and mixed method training [10, 12-14]. However, explosive power expressed in the weight room does not always transfer to an increase in performance on the pitch [15]. Most weight room training methods rely heavily on long ground contact times to develop maximal concentric muscular force [16-18]. This is in contrast to the short contact times of less than 240ms observed in sprinting and jumping [19] where the majority of force generated comes from the storage and release of energy from passive structures in the muscle [20-22]. Plyometrics are a different brand of exercise that offer a ‘link’ between the heavy strength and ballistic exercises that dominate the weight room and the short rebounding type movements observed on the pitch.

Plyometric exercise interventions have repeatedly shown increases in explosive muscle power metrics, including increases in jump height (JH) [23-28], power output (PO)[25, 29] and reactive strength index (RSI)[23-26, 29, 30]. However, there is an in equivalence between plyometric intervention studies when assessing game performance measures. While some studies report concurrent increases in linear sprinting and measures of agility [23, 24, 27, 31], others report no change in these variables despite significant increases in JH, PO and RSI[24, 27]. This is interesting for two reasons. Firstly, while some researchers claim to be using plyometric exercises, many fail to report their use/lack of technical cues to ensure the exercises are being performed technically correct [32, 33], and secondly, many studies use untrained participants who will likely obtain muscular power adaptations regardless of whether the exercises are performed well or not. To obtain increases in ‘real world’ tests such as sprinting there needs to be not just a change in muscle architecture but also an improved ability to utilise and express the new force capacity [34], through changes in the technical execution of certain movements. Thus, poor technical execution of plyometric exercises during interventions may explain the presence of these unequivocal results.

If the poor technical skill level is the problem in these cases, it may leave many athletes unable to continue improving their elastic force production capabilities past those associated with the “novel” stimulus. In order to reduce the possibility of this, interventions should also focus on appropriate cuing and methods for improving technical skill [35, 36]. Proper plyometric technique is characterised by maintaining system stiffness, preparing properly for and executing a rapid ground contact [33, 37-40]. However, one must not simply the correct execution of technique but also be aware of how it might be taught to others who are unfamiliar with it. Classic models of motor skill development often describe technique acquisition as a three-stage process [41, 42]. The individual first develops a motor plan of the movement (cognitive phase), they then attempt to execute this motor plan and adjust it via repetitions and feedback, i.e. external cuing or internal feeling (associative phase) before eventually the perfected motor plan becomes engrained and reflexive (autonomous phase). With this in mind, it is possible that the reflexive nature of plyometric actions may make it difficult for the learner to obtain adequate feedback and adjust their motor plan accordingly during the associative phase.

A potential means by which to tackle this issue is to increase the flight time (FT) during jumps allowing the learner an increased opportunity to think and adjust their motor plan during repetitions. A greater FT would also allow coaches more time to observe the technical model presented to them during the activity and use appropriate cues to adjust technical deficiency appropriately at the time of execution. The use of resistance bands to assist the reps is an empirically supported method of increasing FT during vertical jumping [43]. Interestingly studies using assisted jumping have showed equivalent if not greater increases in JH [44-47], RSI [44] and power output [46, 47] compared to “traditional” ground-based interventions. Furthermore, Khodaei, Mohammadi [48] and colleagues showed that a 4 week assisted plyometric intervention was superior to a “common” plyometric intervention for improving field test measures of speed and agility. In addition, external assistance has been shown to reduce the load placed on the system during plyometric and jumping activities [44, 49] potentially resulting in lower muscle damage/fatigue post sessions, this would be preferable for sport teams that have high volumes of fatiguing technical training. However, assisted plyometrics have, up to this point, only been considered from an over speed training perspective and no previous research has investigated their potential for skill development to the best of the author’s knowledge.

Thus, the current study will aim to compare the effectiveness of an assisted plyometric training intervention to a “traditional” ground-based intervention in producing changes in vertical jumping kinetics. Previous research has suggested that < 30% body mass unloading (BMU) is insufficient to generate an over speed stimulus [47], thus differences between groups across the intervention are likely to be as a result of the inclusion/exclusion of assistance while learning, rather than separate stimuli. It is hypothesized that the assisted plyometrics intervention will display greater improvements in vertical jumping kinetics than the ground-based plyometrics group following the intervention period. The investigation presents a null hypothesis that both the assisted and unassisted study groups will display equivocal changes in vertical jumping kinetics across the study period.

2. METHODS

Experimental Approach to the Problem

The aim of this study was to compare the effects of assisted vs non-assisted plyometric interventions over a 6-week period on a number of explosive power performance tests including; countermovement jump (CMJ), drop jump (DJ) and sub maximal hopping (SH). Sample size was selected based on training group sizes (numbers are participants per training group not total participants) in previous research showing statistically changes inRSI [44, 50] and CMJJH[45, 50] (n = 11, 10 and 7 respectively). Following the pre-intervention testing session participants were randomly assigned to 2 groups. An assisted plyometrics group (BAP; n = 8) who completed all the exercises in the intervention using resistance bands to assist their jumps and a traditional ground based plyometrics group (GBP; n = 7) who completed the same program but without assistance. Participants were assigned a number based on the alphabetical order of their surnames. The numbers were then entered as the range for a random number generator. The first number generated was assigned to the BAP group and the second to the GBP group and so on until all names had been generated. The use of a third group that completed no plyometric training was considered but it was decided that entry in the control group would disadvantage those players from potential physical development, therefore ethical reasoning dictated would only be two groups.

2.1. Subjects

15young male soccer players were recruited from the Professional Development Phases (Under 18-Under 17) of a prominent Football League One Academythrough email communication. Participant descriptive measures were as follows; Age 17.3 ± 0.6 years; Standing stature, 179.2 ± 5.93 cm; Mass, 96.3 ± 6.33 kg. There were no significant differences between anthropometric characteristics across groups. Due to all participants being from the same soccer academy, training load was similar across groups for those who completed the study. However, there was a slight trend toward greater training loads in the assisted group ($P = 0.062$) with training load at 25132 ± 4343 arbitrary units (AU) and 19297 ± 5771 AU in the BAP and GBP groups respectively. Inclusion criteria were as follows; 1) Is involved in the football academy in question as a full-time scholar 2) No current or previous injuries in the last 6 months that would prevent or hinder jumping ability 3) Limited previous exposure to specifically programmed rebound plyometrics. The parents/guardians and participants were provided information sheets detailing the potential risks/benefits of participating in the study and the participants were required to complete and pass a Physical Activity Readiness Questionnaire (PAR-Q) in order to be included. Participants then signed an informed consent form prior to commencement of the study, parental/guardian assent was also provided. Prior to commencing the study, the researchers set a minimum of 8 completed sessions for inclusion in the final analysis. This cut off was chosen as in previous literature a 4-week intervention with 2 sessions per week (8 sessions total) appears to be the minimum effective dose for improving vertical jumping kinetics and measures of muscle stretch shortening adaptations[30, 51, 52]. The study conformed to the guidelines of the Declaration of Helsinki and was approved by the Cardiff Metropolitan University Ethics Committee.

2.2. Testing Procedures

Participants were familiarized to the testing procedures in a single session conducted at their football training facility one week prior to actual testing. A second familiarisation session was held at their usual strength and conditioning facility to familiarise them with the protocol for the plyometric intervention one week prior to its start date. Participants were randomly assigned to their training groups immediately after the initial testing session to double blind the testing. The testing was scheduled on a day that allowed for >24hr rest from vigorous training or match play and the participants were instructed to maintain normal sleep and nutritional intake prior to attending the session. All researchers were present at both testing sessions and verbally encouraged players to elicit maximum effort during data collection. All tests were completed within a 4-hour window on a single day at the participants normal football training facility. Participants arrived in pairs and were allocated a 30-minute window to complete the testing. An additional hour was included for extended data collection time requirements. The tests completed were; a maximal effort CMJ, a 50cm DJ and a 20-jump SH test to a metronome, all jumps were performed with hands on hips (akimbo) to better isolate the contribution of explosive leg power [53]. A standardized warm-up procedure (Table 1) was completed by each participant immediately prior to their testing slot and one minutes rest was given between tests so as to ensure maximal physical readiness for each test.

Table 1: *A table displaying the standardised warm-up procedure that preceded the start of each testing session for all participants.*

Order	Exercise	Reps	Intensity
1	Steady state bike	3 minutes	Low [a]
2	Banded squats [b]	10	Green band/ Bodyweight
3	Single leg RDL	10 each side	Bodyweight
4	Alternate lunges	10 each side	Bodyweight
5	Adductor swings	10 each side	Bodyweight
6	Countermovement jump	3	50%
7	Countermovement jump	3	75%
8	Countermovement jump	3	90%

Note: RDL: Romanian Deadlift. Bodyweight denotes 'without external load'

[a] Players were instructed to work at a 5/10 rating of perceived exertion

[b] Banded squats were performed with a standard resistance green mini band with players legs placed shoulder width apart and the band located around the knees

2.2.1. Anthropometric Measurements

Standing stature was assessed using a stadiometer (SECA, seca GmbH & Co. KG, Germany). Participants were instructed to remove their shoes, stand on the stadiometer, take a deep breath in and hold it until the measurement was completed. Body mass was measured using electronic scales (SECA, seca GmbH & Co. KG, Germany) and participants were instructed to remove excess items of clothing prior to the recording of body mass.

2.2.2. Countermovement Jumps

CMJ's were performed on a set of unilateral force plates (PASCO, PASCO scientific, CA, USA). Participants were instructed to place their hands on their hips (akimbo) so as to isolate lower body power contribution. They were instructed to initiate the jump by performing a rapid downward movement to approximately a quarter squat position (120° knee flexion; see Figure 1), then explode powerfully upward immediately and land upright but "absorb the floor" on landing. For the jump repetitions, participants stepped onto the plates and were instructed to "stand as still as you can" while the force plate calculated mass data. A researcher then counted "3, 2, 1, Jump" and participants were instructed to initiate their countermovement on the "Jump" cue. They were then requested to "stand as still as you can" again after landing. Participants were then allowed a moment to readjust their foot position prior to the next jump. Force plate data was then entered into an excel spreadsheet based on empirical research[54] where it was subject to further analysis to derive jump height (JH) and peak power output (PPO) data. All participants performed 3 repetitions, with their highest JH and PPO recorded as their test score.

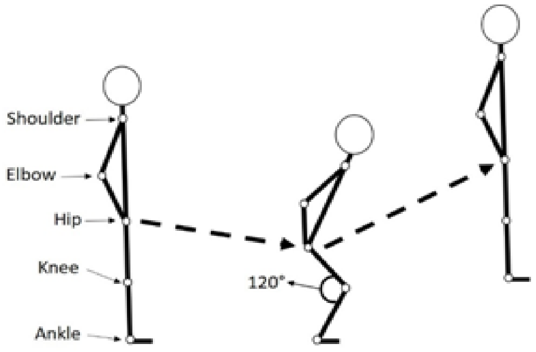

Figure1: *A diagram showing the positioning of the shoulder, elbow, hip, knee and ankle for the desired countermovement jump technique that was decided on by researchers and described to participants.*

2.2.3. Drop Jumps

Drop jumps were performed on a contact mat (SMARTSPEED, Fusion Sport, QLD-Australia). Participants stood on top of a 50 cm box and were instructed to put their hands on their hips (akimbo) and step off the box with their ankle angled towards the ceiling (dorsiflexed; see Figure 2). They were instructed to land with both feet and "bounce" off the floor minimizing ground contact time (GCT) while also maximizing JH as recommended in empirical technical models[22, 33]. Participants were told to drive their foot into the floor to initiate the rebound motion. Every participant completed three repetitions with 30s rest in-between. The RSI for each jump was calculated in the Smart Speed phone application and their best RSI score of the three jumps was recorded as their test score. The best RSI value was then split into its separate components GCT and JH for further analysis.

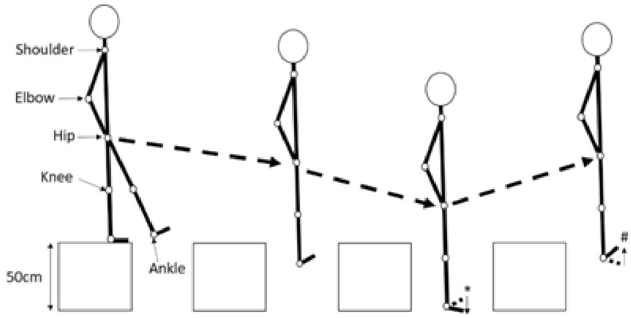

Figure2: *A diagram showing the positioning of the shoulder, elbow, hip, knee and ankle for the desired drop jump technique that was decided on by researchers and described to participants.*

2.2.4. Submaximal Bilateral Hopping

The submaximal hopping test was performed on a contact mat (SMARTSPEED, Fusion Sport, QLD-Australia). Participants were instructed to place their hands on their hips (akimbo) and stand in the center of the mat. An audible digital metronome was then started at 2.0 Hz and participants were instructed to hop to the tempo dictated by the metronome. Participants initiated their first jump using a countermovement (see Figure 3). Participants were not instructed to maximise JH or minimise GCT as the test is designed to enable them to self-optimise JH and GCT to match the metronome. Participants completed 20 hops per test and the average of their RSI score for the middle 10 was recorded as their test score. The average of the separate components of RSI (GCT and JH) were also averaged for further analysis. If both researchers agreed that the participant had not jumped syncronised with the metronome to the required standard the participant was asked to repeat the test. In this circumstance the test was only repeated once so as not to induce unnecessary fatigue.

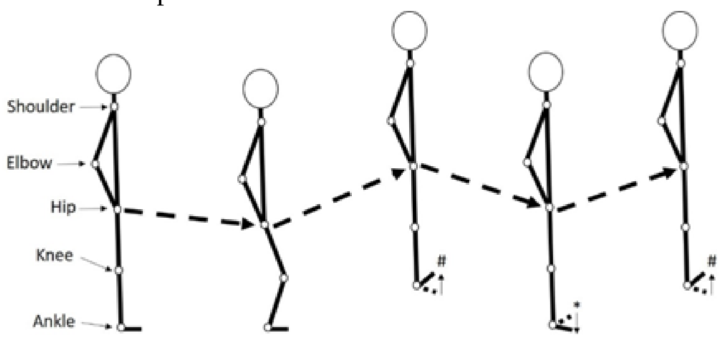

Figure 3: *A diagram showing the positioning of the shoulder, elbow, hip, knee and ankle for the desired repeated hopping technique that was decided on by researchers and described to participants.*

Training protocol

Following pre-testing, both groups were given two weeks of normal training as dictated by their strength and conditioning practitioner at the football academy before the intervention commenced. The program followed a progressive loading pattern with an increasing number of foot contacts per week based on a previous study by Ramírez-Campillo and colleagues [23] and following previous recommendations for beginner athletes[55]. The intervention exercises mirrored that of the testing exercises and thus was a mixture of explosive ballistic (CMJ) and rebound plyometrics (DJ and SH), full details of the program are provided in Table 2. All jumps were performed 'akimbo'. GBP and BAP groups were matched for volume-load, with the only difference in training programs being the addition of resistance bands in the BAP group to assist their reps. The intervention sessions were completed at an indoor strength and conditioning facility and were delivered and coached by members of the research group. The intervention exercises were completed at the start of the participants usual strength and conditioning sessions and did not interferewith any other aspects of their regular training activities. GBP and BAP groups completed identical sessions with the same rest between sessions (48 hrs) and sets (60s).

Table 2: *A table displaying the training protocol including exercises, sets, reps and progression across weeks.*

	Volume (sets x repetitions)		
Exercise	*Weeks 1-2*	*Weeks 3-4*	*Weeks 5-6*
Counter-movement jumps	3 x 5	4 x 5	5 x 5
30 cm drop-jumps	3 x 5	4 x 5	5 x 5
Bilateral hops	5 x 10	5 x 10	5 x 10
Total foot contacts	80	90	100

2.2.5. Determining Assistance

Participants were re-weighed on the first day of the training intervention and this was used as their body mass for assistance calculations. The resistance bands were positioned around the top of a standard squat rack (Figure 4) and held by the participants (Figure 5). This method was chosen in place of the traditional harness based system often observed in research [56] as it is has been shown to achieve greater FTs at the current studies desired unloading [43]. It is also more relevant to field practitioners making it more conducive to the scope of this study. Participants were told to "pull the band into the chest and lock the elbows in" using the cue "knuckles to nipples". This process was completed to ensure consistency in anatomical location and tension of the bands while jumping. Participants were instructed to hold the band and step onto the scales where their reduced body mass was recorded. A coefficient of variation using 5 separate measurements was calculated if the unloading was 20-30% of body mass. If an un-loading of 20-30% was not achieved then the number and/or colour of the bands was changed until this was achieved.

All players used a combination of orange and red bands (Perform Better, Perform Better Ltd., Warwickshire, UK) to generate adequate assistance. A breakdown of achieved un-loading and coefficients of variation for each player is provided below in (Table 3). Participants used the same assistance throughout the entire training protocol.

Table 3: *A table displaying the variation in achieved body mass unloading using the band set-up for each participant.*

		Body mass unloading (%)					
PP	*Band(s)*	*Trial 1*	*Trial 2*	*Trial 3*	*Trial 4*	*Trial 5*	*CV*
1	R	18.2	18.5	17.0	18.7	17.7	4%
5	O x 2	20.9	20.9	20.6	19.8	20.5	2%
6	R	18.6	19.5	18.7	18.4	18.7	2%
7	R	21.2	22.6	20.8	19.7	20.7	5%
9	R	20.5	21.2	20.5	21.7	21.8	3%
10	R + O	17.9	16.2	16.9	17.3	17.7	4%
13	R	20.2	20.4	20.1	20.1	20.5	1%
15	R	23.5	24.3	23.2	22.7	23.3	2%

Note: PP: Participant ID. CV: Co-efficient of variation. R: Red band. O: Orange band.

2.2.6. Use of cueing

As the study is focused on evaluating the contribution of technique development to changes in force/power expression, it was essential that consistent, effective cues were used and available to all participants [36, 39]. During all activities, the participants were encouraged to focus on actively dorsi-flexing the foot in preparation for ground contact. This was achieved via the cue "toes to ceiling". Participants were also instructed to hold their foot in the dorsiflexed position for "as long as possible" prior to ground contact. During rebound jumps participants were cued to aggressively plantar-flex their foot into the floor immediately prior to ground contact. The cues "drive your feet into the floor" and "push the floor away from you" were used for this. To ensure minimal ground contact time the cues "bounce like a ball" and be "springy off the floor" were used. To ensure the majority of the stimulus was applied to the ankle joint participants were cued to forcefully contact their quadriceps and glutes like they were "trying to cramp them" in order to maintain leg stiffness and minimise knee bend. Finally, participants were all encouraged to apply maximal effort to all jumps by using cues such as "explode upwards" "drive hard upwards". All participants received consistent cuing from all members of the research team.

2.3. Statistical Analysis

Descriptive statistics (□ ± SD), mean difference (95% confidence interval [CI]) and effect size (95% CI) are provided for pre and post-training intervention data. All data were checked for normal distribution using the Sharpiro-Wilk test, as well as skewness and kurtosis values and it was noted if normal distribution was violated. Separate mixed-model analysis of variance (ANOVAs) were used to explore potential significant changes in all training variables using group as the between subject factor (2 levels, BAP and GBP) and time as the within subject factor (2 levels, pre-test and post-test).Thus, all models were 2 way (group x time). Ryan-holm Bonferroni stepwise adjusted post hoc tests were used to determine the origin of any significant effects revealed by the ANOVA. For non-normal data, stepwise adjusted Wilcoxon Signed Rank tests were used where appropriate. Statistical significance was accepted at the alpha level$p \leq 0.05$. Descriptive statistics and post hoc tests were completed in Microsoft Excel®, whereas all other analysis was carried out using SPSS V23.0 for windows (SPSS®, IBM Corp., United Kingdom).

3. Results

Inclusion and exclusion from analysis

Over the course of the study 2 participants failed to meet the minimum session attendance. One participant was unable to complete adequate sessions due to a back injury. The second participant was frequently called into the older age groups for training and therefore was unable to attend enough sessions. Participant recruitment, dropout and session attendance figures are presented below (Figures 6 and 7).

3.1. Countermovement Jump

3.1.1. Jump Height (JH)

Post-test CMJ JH was found to be non-normal in nature. Despite this, kurtosis and skewness values were deemed to be acceptable and thus parametric tests were used to compare this data to the pre-test. Pre-test CMJ JH was 0.26 ± 0.045 m and 0.27 ± 0.022 m in the BAP and GBP groups respectively. This increased to 0.40 ± 0.076 m (Mean Difference [MD] = 0.13 m [CI = 0.09-0.17]) and 0.37 ± 0.073 m (MD = 0.10 m [CI = 0.06-0.15]) in the post-test respectively. The ANOVA showed a significant main effect of time ($F_{(1,11)} = 58.53$, $p < 0.01$) but did not show a significant interaction effect ($F_{(1,11)} = 1.01$, $p = 0.33$) or a significant main effect of group ($F_{(1,11)} = 0.07$, $p = 0.80$). Post-hoc testing showed a significant increase in JH pre vs post-testing for both the BAP ($p < 0.01$; Effect size [ES] = 2.11 [CI = 1.21 to 3.01]) and GBP ($p < 0.01$; ES = 1.87 [CI = 0.77 to 2.97]) groups (see Figure 8).

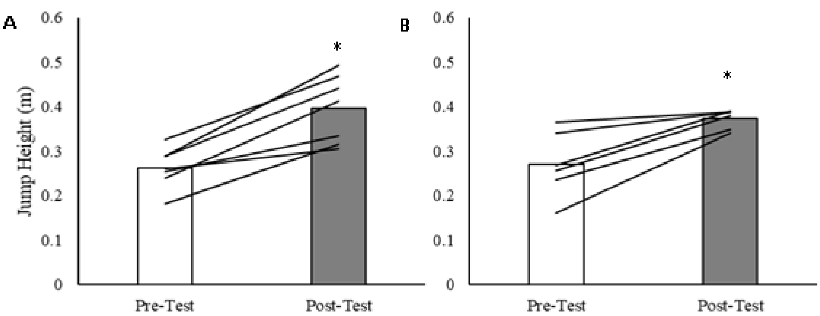

Figure 4: *Graphs showing the change in CMJ JH from pre to post testing following the training intervention. Bars represent the mean change for each group and the black lines represent individual responses. Graph A = BAP group and B = GBP group. * denotes a significant difference (p< 0.01) pre vs post-test. NB: BAP = Band assisted plyometrics. GBP = Ground based plyometrics. CMJ JH = Countermovement jump height.*

3.1.2. Relative Peak Power Output (RPPO)

Pre-test CMJ RPPO was 46.16 ± 5.900 $W.kg^{-1}$ and 46.35 ± 7.889 $W.kg^{-1}$ in the BAP and GBP groups respectively. This increased to 57.31 ± 7.411$W.kg^{-1}$ (MD =11.15 $W.kg^{-1}$ [CI = 8.00-14.3]) and 54.85 ± 4.195$W.kg^{-1}$ (MD =8.50$W.kg^{-1}$[CI = 3.71-13.29]) in the post-test respectively. The ANOVA showed a significant main effect of time ($F_{(1,11)}$ = 47.28, p< 0.01) but did not show a significant interaction effect ($F_{(1,11)}$ = 0.86, p = 0.37) or a significant main effect of group ($F_{(1,11)}$ = 0.12, p = 0.74). Post-hoc testing showed a significant increase in RPPO pre vs post-testing for both the BAP (p = 0.01; ES = 1.67 [0.99 to 2.34]) and GBP (p = 0.05; ES = 1.35 [0.35 to 2.34]) groups (see Figure 9).

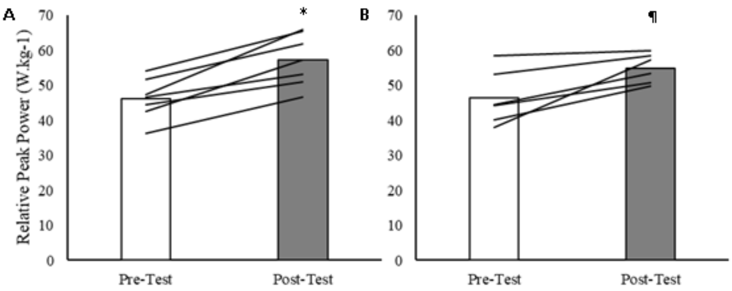

Figure 5: *Graphs showing the change in CMJ RPPO from pre to post testing following the training intervention. Bars represent the mean change for each group and the black lines represent individual responses. Graph A = BAP group and B = GBP group. * denotes a significant difference at p< 0.01 and ¶ denotes a significant difference at p< 0.05 pre vs post-test. NB: BAP = Band assisted plyometrics. GBP = Ground based plyometrics. CMJ RPPO = Countermovement relative peak power output.*

3.1.3. Drop Jump

Pre-test DJ RSI was 1.36 ± 0.444 and 1.58 ± 0.469 in the BAP and GBP groups respectively. This decreased to 1.34 ± 0.290 (MD = -0.02 [CI = -0.28-0.24]) and increased to 1.98 ± 0.359 (MD =0.40 [CI = 0.05-0.75]) in the post-test respectively. The ANOVA did not show a significant main effect of time ($F_{(1,11)}$ = 3.05, p = 0.11) or interaction effect ($F_{(1,11)}$ = 3.78, p = 0.08), but did show a significant effect of group ($F_{(1,11)}$ = 5.09, p = 0.05). Post-hoc testing showed that while neither the BAP or GBP groups significantly increased DJ RSI from pre to post-intervention (p = 0.88 and ES = -0.06 [-0.93 to 0.82]; p =0.15 and ES = 0.97 [-0.48 to 2.41] respectively [see Figure 10]) the GBP group had a significantly higher DJ RSI compared to the BAP group in the post-test (p < 0.01; ES = 1.97 [0.74 to 3.19]) while no significant difference existed in the pre-test (p = 0.41; ES = 0.47 [-0.74 to 1.69]; see Figure 11). When the ANOVA was run with GCT it revealed a significant effect of time ($F_{(1,11)}$ = 6.85, p = 0.02) and group ($F_{(1,11)}$ = 4.86, p = 0.05) but no significant interaction effect ($F_{(1,11)}$ = 0.19, p = 0.67). The ANOVA for JH revealed no significant effect of time ($F_{(1,11)}$ = 2.51, p = 0.141), group ($F_{(1,11)}$ = 0.02, p = 0.90) or interaction ($F_{(1,11)}$ = 1.10, p = 0.316). When post-hoc tests were run it revealed a significant difference between the groups in the post-test for GCT. No other changes were significant (see Table 4).

Table 4: *A table showing the pre-test means (± SD), mean changes displayed with 95% CI and the significance level of pre- versus post- mean change during the DJ.*

Group	Test	Pre-test mean	Mean difference (95% CI)	P value (ES [95% CI])
BAP	GCT (s)	227.6 ± 91.13	-35.1 (-86.68 to 16.40) [a]	p = 0.23 (-0.46 [-1.29 to 0.38])
	JH (cm)	35.0 ± 5.32	-3.5 (-7.27 to 0.28)	p = 0.12 (-0.68 [-1.61 to 0.24])
GBP	GCT (s)	220.2 ± 26.50	-49.2 (-80.79 to -17.54) [a]	p = 0.06 [-1.78 (-3.64 to 0.08])
	JH (cm)	33.9 ± 6.52	-0.7 (-4.18 to 2.76)	p = 0.71 [-0.14 (-1.03 to 0.75)]

Note: DJ: Drop jump. SD: Standard deviation. CI: Confidence interval. ES: Effect size. BAP: Band assisted plyometrics. GBP: Ground based plyometrics. GCT: Ground contact time. JH: Jump height.

[a] *Significant difference between BAP and GBP groups in the post-test (p = 0.04; ES = -1.5 [-3.00 to -0.04])*

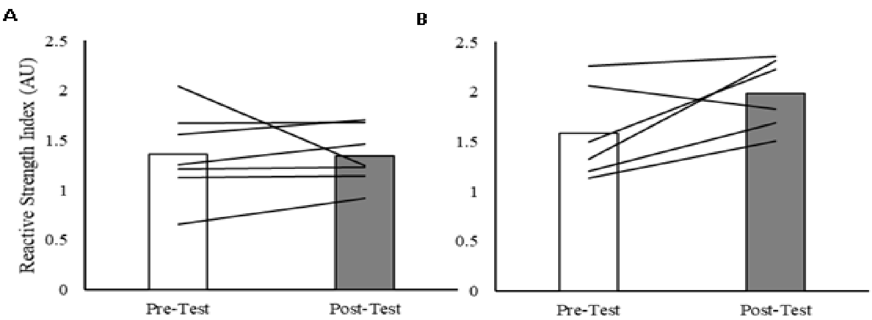

Figure 6: *Graphs showing the change in DJ RSI from pre to post testing following the training intervention. Bars represent the mean change for each group and the black lines represent individual responses. Graph A = BAP group and B = GBP group. NB: BAP = Band assisted plyometrics. GBP = Ground based plyometrics. DJ RSI = Drop jump reactive strength index. AU = Arbitrary Units.*

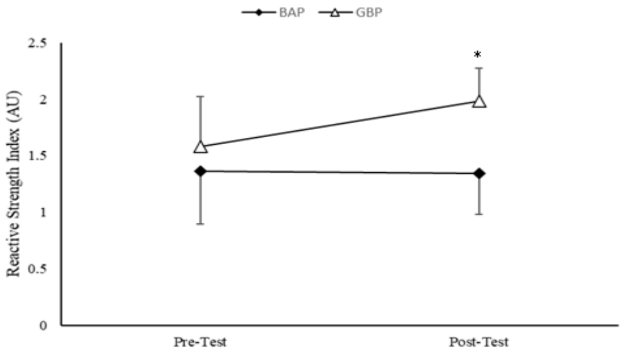

Figure 7: *Graph showing the mean change in DJ RSI from pre to post testing following the training intervention. Values are presented as means with standard deviation error bars. * denotes a significant difference at p< 0.01 between BAP and GBP. NB: BAP = Band assisted plyometrics. GBP = Ground based plyometrics. DJ RSI = Drop jump reactive strength index. AU = Arbitrary Units.*

Submaximal Hopping

Pre-test SH RSI was 0.86 ± 0.152 and 0.82 ± 0.298 in the BAP and GBP groups respectively. This increased to 0.90 ± 0.106(MD = 0.04 [CI = -0.07-0.16]; ES = 0.27 [-0.89 to 1.43]) and 0.91 ± 0.103 (MD = 0.09 [CI = -0.12-0.30]; ES = 0.41 [-0.83 to 1.65]) in the post-test respectively (see Figure 12). The ANOVA did not show a significant main effect of time ($F_{(1,11)} = 1.13$, $p = 0.31$) or group ($F_{(1,11)} = 0.03$, $p = 0.87$) and did not display any interaction effect ($F_{(1,11)} = 0.23$, $p = 0.65$). When the ANOVA was run with GCT it revealed no significant effect of time ($F_{(1,11)} = 2.63$, $p = 0.13$), group ($F_{(1,11)} = 0.08$, $p = 0.79$) or interaction effect ($F_{(1,11)} = 0.25$, $p = 0.63$). The ANOVA for JH revealed no significant effect of time ($F_{(1,11)} = 0.88$, $p = 0.37$), group ($F_{(1,11)} = 0.32$, $p = 0.57$) or interaction ($F_{(1,11)} = 0.68$, $p = 0.43$) see Table 5 for means and mean changes.

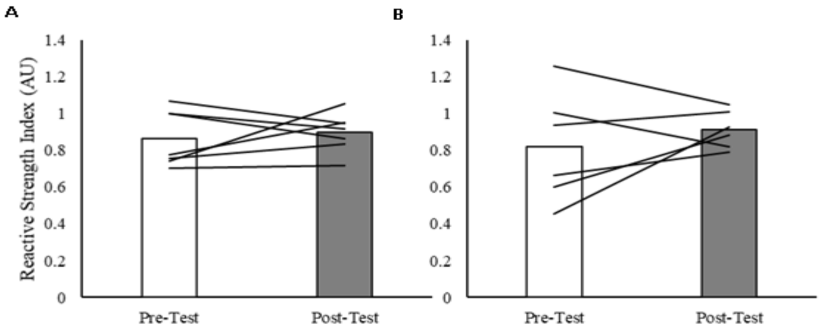

Figure 8: *Graphs showing the change in SH RSI from pre to post testing following the training intervention. Bars represent the mean change for each group and the black lines represent individual responses. Graph A = BAP group and B = GBP group. NB: BAP = Band assisted plyometrics. GBP = Ground based plyometrics. SH RSI = Submaximal hopping reactive strength index. AU = Arbitrary Units.*

Table 5: *A table showing the pre-test means (± SD), mean changes displayed with 95% CI during SH.*

Group	Test	Pre-test mean	Mean difference (95% CI)	P value (ES [95% CI])
BAP	GCT (s)	167.4 ± 16.57	-7.04 (-18.25 to 4.16)	p = 0.26 (-0.53 [-1.59 to 0.52])
	JH (cm)	14.2 ± 1.20	0.06 (-1.06 to 1.19)	p = 0.91 (0.06 [-1.18 to 1.29])
GBP	GCT (s)	172.9 ± 32.35	-13.33 (-36.66 to 9.99)	p = 0.31 (-0.56 [-1.84 to 0.7
	JH (cm)	13.3 ± 2.69	1.01 (-1.05 to 3.08)	p = 0.38 (0.51 [-0.85 to 1.87])

Note: SH: Submaximal Hopping. SD: Standard deviation. CI: Confidence interval. ES: Effect size. BAP: Band assisted plyometrics. GBP: Ground based plyometrics. GCT: Ground contact time. JH: Jump height.

4. Discussion

Whilst the benefits of assisted jumping are well documented from an over speed perspective, its application and effectiveness as a skill development tool are relatively unknown. This was the first study to evaluate whether assisted jumping with a reduced over speed stimulus

(BMU < 30 %) could produce greater changes in vertical jumping kinetics than a similar unassisted program. Both BAP and GBP groups significantly improved leg power measured by CMJ JH (MD = 0.13 m [CI = 0.09-0.17]; ES = 2.11 [1.21 to 3.01] and MD = 0.10 m [CI = 0.06-0.15]; ES = 1.87 [0.77 to 2.97] respectively) and RPPO (MD = 11.15 W.kg-1 [CI = 8.00-14.3]; ES = 1.67 [0.99 to 2.34] and MD = 8.50 W.kg-1 [CI = 3.71-13.29]; ES = 1.35 [0.35 to 2.34] respectively). Additionally, neither group significantly improved reactive leg strength measured by change in DJ (MD = -0.02 [CI = -0.28-0.24]; ES = -0.06 [-0.93 to 0.82] and MD = 0.40 [CI = 0.05-0.75]; ES = 0.97 [-0.48 to 2.41] respectively) and SH RSI (MD = 0.04 [CI = -0.07-0.16]; ES = 0.27 [-0.89 to 1.43] and MD = 0.09 [CI = -0.12-0.30]; ES = 0.41 [-0.83 to 1.65] respectively). However, there was a significant difference in favour of the GBP group compared to the BAP group in the post-test DJ RSI ($p < 0.01$; ES = 1.97 [0.74 to 3.19]), where no such difference had existed in the pre-test. Overall, these results show that while the participants in this sample successfully improved leg power, the interventions effect on reactive strength was inconclusive. Moreover, neither group was superior in their change in any of the variables, leading the author to accept the null hypothesis.

The increase in CMJ JH indicates that the intervention substantially increased ballistic leg power in this population, which agrees with previous research evaluating the effects of 'traditional' plyometric and ballistic combined programs on leg power [23, 24, 27]. Indeed, Thomas, French [27] and colleagues showed that a six week intervention with two sessions per week resulted in moderate to large changes in CMJ jump height when using either DJ or CMJ focused conditions (ES = 0.7 and 1.3). Although these changes are substantially lower than the current study (ES = 2.11 [1.21 to 3.01]; ES = 1.87 [0.77 to 2.97] for BAP and GBP respectively) this is likely due to the current study combining the two exercises into the intervention, whereas the aforementioned study used them in isolation. The assisted group data is harder to compare as no data currently exist using similar plyometric, ballistic combination interventions and noting CMJ JH as an outcome variable. However, ballistic only CMJ focused programs are well established at improving CMJ JH which agrees with the findings in the BAP group [45-47, 49]. Interestingly, this is despite the current studies use of low BMU to reduce the over speed training stimulus. However, Argus, Gill [49] and colleagues also managed to show small (6.7 ± 9.7 %) increases in jump height over a 4 week period with a similar training group size (n = 9) in a sample of rugby players. This increase is lower than the current studies (52 ± 22 %), although again this is likely a product of the inclusion of plyometric drills alongside the CMJ during the intervention period.

On the other hand, the study failed to show a significant improvement in JH relative to the unassisted condition as other studies have done previously [45, 49]. Sheppard, Dingley [45] and colleagues showed a significant improvement in their assisted CMJ condition relative to their unassisted condition following a 5-week intervention in a sample of seven junior volleyball players. A possible explanation for this in equivalence is the current study's use of a deliberately low assistance level to remove over speed training effects. Although, while the Sheppard study used an absolute assistance of 10 kg, further calculations based on the mean body mass of their sample (84 ± 7.2 kg), show that assistance level in the study was only 11-14% BMU, 6-9 % lower than the current study. A caveat to this comparison is that the current study used a combination of plyometric and ballistic exercises while the Sheppard study used ballistic only. Ballistic only methods with such low BMU would result in similar mechanical load across conditions [43]. Plyometric and ballistic hybrid programs would likely lend themselves towards greater mechanical loading in an unassisted group due to the use of bands in an assisted group during the DJ. The bands likely decelerated participants during the initial drop during the DJ, reducing heavy impact eccentric stretch loads. Improvements in JH are governed on some level by changes in neuromuscular function [57] and thus rely in part on mechanical training load [58]. Therefore, the higher mechanical load in the GBP group may have cancelled out some of the advantage of the BAP group, thus resulting in equivalent results, despite BAP improving marginally more than GBP (52 ± 22 % vs 46 ± 37 %respectively).

Further to the increase in JH, there was also a significant increase in RPPO across conditions, which again agrees with previous literature for unassisted [25, 29] and assisted [45, 49] conditions. This possibly resulted from the progressive increase in foot contacts per week stimulating muscle level adaptation and improvements in neuromuscular coordination [59]. However, as no physiological measures were taken this is only speculation.

The lack of between group changes again makes the findings of this study different to those previously published comparing assisted and unassisted jumping [45, 49]. As before, it is difficult to unpick the inequivalence of these data due to there being no directly comparable research using ballistic, plyometric combination programs. Interestingly, both groups followed similar patterns when comparing the mean differences in RPPO and JH as percentage change (JH MD = 52 ± 22 % and 46 ± 37 %; RPPO MD = 24 ± 10 % and 20 ± 17 % for BAP and GBP respectively). Despite no regression or significance analysis being run to compare these data, on visual inspection it would seem that the relative increase in RPPO is much lower than the increase in JH. Therefore, another factor may have also contributed to the large increase in JH across the study. The participant samples were deliberately selected to be 'novice' jumpers and thus a change in jumping technique possibly played a large role in the changes in JH. Indeed, previous literature has shown that clear and focused cuing can improve jumping technique in inexperienced jumpers over short time periods [36], although interestingly, it would appear that, research evaluating the effects of cueing on CMJ kinematics in novice athletes is conspicuous by its absence. Overall, it is clear that both the assisted and unassisted methods used in this investigation are sufficient to induce increases in leg power and jump height over a short 6-week period in youth football players. Further research could also look to unpack the relative contributions of physiological adaptations vs skill development and whether focused cuing has a chronic effect on CMJ technique.

In contrast to the CMJ, DJ RSI showed no significant change in either group, a finding that is in stark contrast to previous literature investigating band-assisted [44] and unassisted conditions [25, 26, 29], even in similar sample groups [23, 24, 30, 50]. Indeed, Ramírez-Campillo, Henríquez-Olguín [23] and colleagues showed that a similar (combination of ballistic and plyometric jumps) 6-week program in a similar population (youth football players) produced a significant increase (36.1 % [1.7 to 82.3], $p \leq 0.05$) in DJ RSI compared to the non-significant change across both groups (4 % [-13 to 21], p = 0.23 and 31 % [7 to 56], p = 0.15) in the current study. It is difficult to pinpoint the exact reasons for the unequivocal findings in this study, although the fact that it was completed in-season may have limited potential adaptations due to high volumes of cardiovascular football training load. Cardiovascular adaptations have been linked in the past to a reduction in strength/power gains in a number of different populations [60]. However, other studies have shown that is possible to induce increases in RSI in-season in young soccer players [23, 24]. Although a caveat here would be that one of the interventions [24] used very low volume, (60 contacts) and high intensity (20, 40 and 60cm drop) exercises which would have induced much faster changes in RSI [38].

While the other study [23] started on a higher volume of contacts (120 vs 80 in the current study) and had a weekly increase in volume, in contrast to the bi-weekly increase observed in the current study. Given that the comparable training group in the current study (GBP) were close to significance (p = 0.15) it is possible that a weekly increase in volume and higher starting number of contacts might have been what was needed to produce significant change. Indeed, mechanical loading is especially important for inducing changes in the elastic recoil properties of the musculotendinous complex that underpin RSI [61].

The lower than expected change in DJ RSI could also be due to the low BMU the study used, resulting in a FT that was too short. Previous research has shown that a 40 % BMU produced a FT 20% longer and a 30 % BMU produced a FT 10% longer than the 20 % BMU that was used in the current study when using the same field based method 43]. Therefore, the generated FT in the current study may not have allowed participants adequate time to adjust and implement the cues given to them. This acquisition and interpretation of feedback during reps is especially important in early stage learning to transfer the motor plan towards a more autonomous execution [41, 42]. However, when the change in RSI is broken down into changes in GCT and JH a different picture emerges. Both groups showed moderate reductions, albeit insignificant, in GCT (MD = -35 ms [CI = -90.81 to 20.53, p =0.23]; ES = -0.46 [-1.29 to 0.38] and MD = -49 ms [CI = -83.82 to -14.52, p = 0.06]; ES = -1.78 [-3.64 to

0.08]) alongside subsequently moderate (MD = -3.50 cm [CI = -7.27 to 0.28]; ES = -0.68 [-1.61 to 0.24]) and small (MD = -0.71 cm [CI = -4.18 to 2.76]; ES = -0.14 [-1.03 to 0.75]) , decreases in JH in BAP and GBP groups respectively. This is especially relevant as a reduction in GCT is potentially more indicative of plyometric skill development than a larger JH [40, 62]. Indeed, as Pedley, Lloyd [33] and colleagues showed, an athlete can produce a significantly greater jump height with poor plyometric technique (large knee bend, GCT > 250 ms), compared to a jump with good plyometric technique (minimal knee bend, GCT < 250 ms). Moreover, while changes in GCT are partly driven by musculoskeletal adaptations [36, 61] they are equally affected by proper foot positioning and movement skill [33, 40, 62]. Thus, the observed reduction GCT in both groups shows that despite our initial hypothesis GBP and BAP may be equally valid for improving plyometric skill, so long as proper coaching and cuing is emphasized. However, while changes in GCT are difficult to achieve solely through mechanical loading of the musculotendinous unit, it is true that greater mechanical loading greatly effects changes in reactive leg strength [61, 63] and it is equally likely that the GBP groups equivalent decrease in GCT may have resulted from a potentially higher exposure to mechanical loading (due to them not using bands during the DJ) during the intervention.

Moreover, if the GBP group did experience greater reactive jumping load, it may explain the significant difference between the GBP and BAP groups in the post test for DJ RSI. While previous data suggests that assisted ballistic only jumping may result in a slight increase in landing forces as BMU increases [43, 47], as mentioned previously assisted DJs are likely to display an opposite trend. Addition of bands would may slow the decent during a DJ, reducing landing impact forces for the BAP group as drop height remained equal. While assisted jumping kinematics suggests that the BAP group would have attained higher impact forces on the second landing due to the bands accelerating JH, these would likely be much lower due to the slow absorptive, eccentric only nature of the landing. This is opposed to the combination of rapid eccentric and expressive concentric nature of the rebound where the GBP possibly experienced greater forces. On visual inspection the GBP group decreased DJ JH by less than the BAP group, suggesting that the larger mechanical load may have stimulated subtly greater leg power adaptations and resulted in the between group difference in RSI [61]. However, as there is no current research directly evaluating changes in DJ kinetic profile in assisted vs unassisted conditions this point is restricted to speculation and future studies may wish to address this. Additionally, researchers might look to replicate the current investigation, adding a second 6-week period with both groups using GBP method and see whether the original BAP group progresses further due to a greater ceiling for mechanical adaption on the back of improved technical proficiency. The addition of kinematic data alongside kinetic data in the testing might also give a more holistic insight into overall changes in performance. Overall, it is possible to conclude from the data available that both assisted and unassisted conditions were equally effective at reducing GCT and eliciting changes in RSI in the DJ in young football players.

Despite both BAP and GBP groups showing positive changes in RSI (MD = 0.04 [CI = -0.07-0.16]; ES = 0.27 [-0.89 to 1.43] and MD = 0.09 [CI = -0.12-0.30]; ES = 0.41 [-0.83 to 1.65] respectively), moderate reductions in GCT (MD = -7.04 [-18.25 to 4.16]; ES = -0.53 [-1.59 to 0.52] and MD = -13.33 [-36.66 to 9.99]; ES = -0.56 [-1.84 to 0.72] respectively) and small to moderate increases in JH (MD = 0.06 [-1.06 to 1.19]; ES = 0.06 [-1.18 to 1.29] and MD = 1.01 [-1.05 to 3.08]; ES = 0.51 [-0.85 to 1.87] respectively) in the SH test, none of the changes were significant. This is in contrast to previous literature showing significant increases in RSI and other variables related to leg stiffness during submaximal hopping following plyometric training in similar populations [30, 64]. Indeed, Hammami, Granacher [64] and colleagues showed that a short (4 week) plyometric intervention produced significant improvements in absolute leg stiffness in a sample of young soccer players. However, neither of the studies showing positive changes [30, 64] can be matched exactly to the current study for training protocol (number of contacts, volume-load progression etc.), exercise selection (ballistic, single leg variations etc.), or subject characteristics (age, training history etc.), making direct comparison difficult. In reality, slight discrepancies in training protocol and exercise selection are common [32] and most studies (including the current study) follow subtly different empirical recommendations on volume load and exercise progression and equivalence between findings is still usual.

However, what makes this study different to those previously published is a significant difference in subject characteristics. Plyometric adaptation is highly age dependent and is different depending on biological maturity in youth, with some lower age bands experiencing greater adaptation than higher ones, mainly due to a higher trainability ceiling [65]. Indeed, both studies showing improvements in SH parameters used 12-15-year-old boys whereas the sample population in the current study ranged from 17-18 years old. Indeed, despite the participants being relative novices to actual jump focused training, in reality they have all been playing a sport that comprises heavily of 'plyometric' activities (sprinting, jumping etc.) for a number of years. This would most likely result in stretch shortening adaptations at some level and therefore inducing further change may take longer, more complex training interventions than seen in the current study. Further to this, the current studies novel use of band assistance, compounds the issue of non-comparable research as no study currently exists evaluating the effect of band assisted plyometrics on submaximal hopping parameters.

The equivalence between groups in terms of changes in SH parameters is especially interesting given the slight trend towards the GBP group being superior in the DJ. Sub maximal hopping is generally a more skill-based examination of one's plyometric ability due to the cyclical phases of pre-activation (foot/ankle positioning), ground contact initiation (driving foot into floor) and elastic energy release (stretch reflex). Indeed, if one were to examine the DJ and SH tests from a motor skill perspective the DJ is an examination of one's ability to recall and execute the motor skill in a closed condition (large planning period prior to single-rep, same drop height), whereas the SH test is more a test of one's ability to repeatedly execute the motor plan in an open environment (subtle changes in JH depending on previous rep, low planning period between reps) and requires autonomous motor plan recall. Thus, based on motor learning theory [41, 42] while the DJ is still a measure of learned skill and requires some autonomy in motor plan recall, the SH test may be a truer measure of skill retention and an ability to adjust the motor plan effectively. Indeed, it may therefore be harder therefore to enhance SH ability through physiological stretch reflex adaptations alone. Therefore, the equivalence across groups in the SH test and trend towards greater scores in the DJ is potentially evidence in these results that the band assisted condition produced more favourable skill adaptations, while the unassisted condition produced more muscle level adaptations. However, this is purely speculation and further research examining kinematic changes at the knee and ankle are required to confirm this.

Finally, further to the above point, the lack of significant change in the SH test for the BAP group may also have been attributed in part to the addition of the bands in their SH while training. Indeed, previous data evaluating kinetic profiles of assisted CMJ jumps found that the 'field based' method employed in this study resulted in higher JHs and greater landing forces compared to bodyweight at 20 % BMU [43]. Due to the self-optimising nature of the SH test, the JH achieved with each rep is supposed to represent the optimal drop height for a shorter GCT for the individual. Thus, it is possible that the addition of bands meant that the BAP group were practicing this skill outside of their optimal range for drop height, causing greater landing forces and interfering with fast stretch shorting responses. Therefore, while the GBP groups were practicing for 6 weeks in optimal test conditions the BAP groups were not. Moreover, the addition of bands to a very fast cyclical skill may have been too much for participants in the BAP to think about, interfering with their internal feedback mechanisms and disrupting learning. This is an interesting consideration for future researchers as they may want to replicate the study but remove assistance from the SH during the training intervention for both groups allowing the BAP group to practice at self-optimal JH. However, as mentioned before, due to no existing literature examining the kinetic profiles of assisted SH, this interpretation is only speculating. In reality, the only evidence backed conclusion the authors are able to draw from the current data is that the BAP and GBP groups responded equivocally to the training intervention in terms of SH performance. Moreover, it remains unclear as to whether the lack of significant change in both groups is linked to age dependent adaptations and thus whether more time, different exercises of greater load was needed to produce changes. This is something future research should look to address.

5. Conclusion

In conclusion these data in the current study show that a 6-week combined plyometric and ballistic progressive volume-based training intervention is sufficient to induce positive changes in leg power measured via a CMJ in a youth football population in both assisted and unassisted conditions. However, the intervention failed to produce positive changes in reactive leg strength in either group in both the DJ and SH tests. There are many potential reasons for this, including but not limited to, insufficient mechanical load, biological maturity of the participants and potential conflicting factors arising from the selected band assistance. This study was the first of its kind to assess all three tests (CMJ, DJ, SH) in a single study to assess differences in vertical jumping kinetics between assisted and unassisted conditions following a training intervention. Further research should consider replication of the current study and confirm the findings across both conditions as well as exploring the reasons for the lack of difference between assisted and unassisted conditions. There is a plethora of current literature examining the effects of band assistance on ballistic vertical jump parameters, however similar studies investigating the potential of assisted vertical plyometrics is comparatively lean. Further studies are required to fully investigate (physiological adaptations, changes in kinetics with varying assistance and kinematic changes) the potential of assisted plyometrics as a coaching and training tool for improving vertical jumping kinetics in sporting populations.

Practically, these data suggest that the inclusion of some ballistic and plyometric jump-based drills during the in-season period can result in significant increases in leg power and jump height in both band-assisted and unassisted groups. These adaptations can be achieved across a relatively short (6 week) period and will positively affect young football players from a sport development standpoint[23, 28, 50], while also previously being linked to reduced injury risk in soccer [66, 67]. Interestingly, the study showed that there was minimal difference between assisted and unassisted conditions in any of the training variables measured. Thus, these data provide the first evidence that combined assisted plyometric and ballistic jumping methods could be a useful and equally effective tool compared to the 'traditional' unassisted method to enhance jumping ability in young football players. Moreover, should sporting practitioners wish to use band assistance to enhance their coaching and cuing process through increased flight time and with minimal overspeed stimulus[46], the current data suggest that at the very least this wouldn't have a detrimental effect on performance.

Alternatively, the results of this study open a question of whether assisted plyometrics should be incorporated as part of a 'long term plan' for plyometric development. There is potential that band assistance may reduce mechanical load allowing players to learn and experience stressful plyometric exercises such as the drop jump, without overt levels of fatigue. This is especially relevant to team sports practitioners who may wish to balance the soreness and fatigue usually synonymous with 'classic' ground based plyometrics [68, 69] with the high levels of volume and fatigue associated with technical training. Indeed, this makes assisted plyometrics an attractive avenue to introduce the exercises to beginners without compromising performance gains. Practitioners might want to use assisted methods at the start of a program using a progressive volume-based approach before incorporating 'classical' plyometrics with a reduction in foot contacts in a 'wave like' fashion. Thus, gradually 'priming' the players for higher intensity, reducing injury risk and creating optimal conditions for development [70]. Finally, the current study did not use the harnesses that are commonly employed in scientific research on assisted jumping and instead opted for more the practically relevant method of bands looped over a squat rack [43]. Therefore, practitioners can be confident that the results of this study are directly transferable to a real-world environment and will not require the purchase and installation of expensive harness-based rig systems to assist jumping.

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