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Title: An Off-season Plyometric and Resistance Training Programme to Improve Vertical Jump Height in Adolescent Female Volleyball Players

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Abstract

Plyometric training has shown to improve vertical jump height, but the design and implementation of a plyometric training programme for adolescents requires consideration of several variables as well as the time of the season. The purpose of this study was to implement a pragmatic programme that improves vertical jump height, and to monitor the effects of a 15 week off-season plyometric and resistance training programme on the vertical jump height in adolescent female volleyball players. Ten adolescent female volleyball players (age: 15.1 ± 0.9 years, height: 1.71 ± 0.04 m, body mass: 63.6 ± 6.0 kg, volleyball training experience: 5.1 ± 1.4 years) underwent 15 weeks of plyometric and resistance training (twice and once a week, respectively). A single-targeted block periodised approach and a linear periodization model were applied. Vertical jump height was assessed before the programme (T1), after 4 weeks (T2), after 12 weeks (T3) and at the end of the programme (T4). Jump height significantly increased by 8.8% over the full time of the investigation. No significant difference was found between T1 and T2 but for all other pairwise comparisons. Similarly, leg power was observed to increase by 6.5% ($p = 0.001$). The 15-weeks training programme showed to improve jump height and leg power. In consideration of its practical nature and its results in comparison with similar intervention studies, the programme suggests practical relevance for coaches.

Keywords

Coaching, periodization, power, stretch-shortening cycle, young.

Introduction

Volleyball is an anaerobic sport that requires strength, speed and explosive power [19, 25]. A crucial factor that can affect volleyball performance is vertical jump ability, which is a key component of success in technical aspects such as spiking and blocking [13, 15]. In adolescence, apart from the focus on constant technical improvement, vertical jump height can optimise volleyball performance [25, 36] and even distinguish between different levels of performance [8, 27].

Several studies have examined the effect of plyometric training on vertical jump height. Stojanovic and Kostic [37] reported that 8 weeks of plyometric training can affect positively the explosiveness type of the muscles which leads to vertical jump height increase. Additionally, they claimed that plyometric training is more effective to improve jump height than volleyball training alone. As plyometric training is not intended to be a stand-alone training programme but augmenting the main programme [6], studies that examined the effect of combined resistance and plyometric training programmes on performance aspects of adolescent volleyball players are more appropriate. For example, Fathi et al. [12] have shown that 16 weeks of combined resistance and plyometric training improved sprint time and vertical jump more than plyometric training alone in male adolescent volleyball players. Similarly, Faignbaum et al. [11] reported that a 6-week programme combining plyometric with resistance training was more efficient than resistance training alone in improving power in adolescent boys.

The design of a plyometric training programme for adolescents, however, requires consideration of variables additional to the training design such as age, physical maturity, years of volleyball and resistance training experience as well as specific plyometric techniques to be used [12, 28]. A detailed overview of the demands of a carefully designed plyometric programme with recommendations for the appropriate implementation of relevant training parameters for youth players was presented by Lloyd et al. [21]. Lack of basic resistance [9, 38] and neuromuscular control [21], in particular, are contraindications for the implementation of plyometrics to ensure improvement can happen without any injuries. As a result, some investigators (e.g. Sankey et al. [33]) employed relevant inclusion criteria that ensured adolescent players would be able to perform the required activities. Naturally, example plyometric training programmes for adults are available in several outlets [1, 30] but similar programmes are considerably scarcer for young athletes, despite calls to avoid treating younger athletes as miniature adults [21 28].

In addition to the factors described above [28], consideration must also been given to the experimental approach. Several of the published protocols rely on experimental approaches, which although necessary to understand the effects in question, are not entirely applicable in practice. For example, in the study by Fathi et al. [12], the players included had little previous plyometric training experience (a common feature in similar studies [28]), and therefore the relevant changes seen may have been augmented by neuromuscular adaptations [21, 28]. Similarly, in Faignbaum et al. [11] the experimental groups trained for 90 minutes, under carefully monitored conditions; a training duration which is unlikely to reflect training time available in regular training programmes. Finally, in either study, there was no clear indication regarding the relevance of the duration of the programmes or how that duration was suitable or influenced for the annual training plan. If applied research is to be directly relevant to the field, a more pragmatic approach is required, which can allow findings to be translated to everyday practices within typical training programmes and with the restrictions (e.g. equipment and training time availability) likely to be met in a local volleyball club.

Time availability, specifically, is particularly challenging to specific conditioning of adolescent volleyball players. As junior high school students, such players have a busy schedule and often cannot invest extra time for additional conditioning training. Indeed, adolescent volleyball teams during in-season will predominantly practice technical and tactical parts of the game, to enhance performance and get the best possible result, whether short or long-term. During off-season, nonetheless, there is a lack of official games and a reduction of the young athletes' out of court activities, enabling potential specific conditioning training. Thus, off-season is an attractive period to apply an effective conditioning programme when the athletes' schedule is more flexible, to prepare them for the demands of the season by enhancing their performance while reducing the risk of an injury.

Findings and recommendations from a recent systematic review [28], reported lack of relevant research in females as well as likely different adaptations to plyometric training between the two sexes, recommending further studies to increase our understanding. The present study, therefore, aimed to explore the benefits of the off-season period in female adolescent players incorporating the relevant guidelines for plyometric training [21, 28]. The objective of this study was to a) present a pragmatic approach of an intervention programme to improve vertical jump height safely, and b) monitor the effects of an off-season plyometric and resistance training programme, in female adolescent volleyball players.

Methods

Subjects

A convenience sample of ten adolescent female competitive volleyball players (age: 15.1 ± 0.9 years, height: 1.71 ± 0.04 m, body mass: 63.6 ± 6.0 kg, volleyball training experience: 5.1 ± 1.4 years) participated in this study. All the subjects were free of injuries that could affect the application of the programme. None of the subjects was taking any medication or participated in any organised athletic practices other than volleyball and all of them had almost similar out of court activities. Subjects and their parents or legal guardians were informed fully about the intervention, and written informed consent was obtained from them. This project was approved by the Institutional Ethics Committee and all procedures were in accordance with the Declaration of Helsinki.

During off-season, all subjects participated in training volleyball sessions (three to 5 sessions per week, duration 1.5 - 2 hours per session) and competed in one match per week with their club's Under-16 or Senior team. All games took place in the region, therefore no considerable travel was required. All of them had at least 1 year of resistance training experience with their volleyball club before the intervention and were familiar with the technique of the resistance exercises.

Measurements

In keeping with the pragmatic approach to the project, the vertical jump height was selected as the measurement mode, as this measure is readily available to most coaches at no cost and without the need for more expensive or sophisticated equipment (e.g. force platforms, jump mats etc). The jump took place against a backboard, which had a measuring tape attached safely and firmly to it. Players stood next to it with their heels together and in contact with the floor, while their spiking arm was stretched vertically over their head and the height their fingertips reached was recorded as the standing score. Consequently, and using a full 3 step volleyball spike approach, the subjects jumped with an arm swing at the same spot and reached as high as they could and that was recorded as the jump score. The difference between the standing and jump score was the jump height. Every subject completed three trials with 60-90 seconds rest between each effort and the highest jump height was kept for further analysis. This type of jumping has been reported to have good validity for volleyball players [24], while the sport-specific approach with the three strides and jumping on the board has been shown reliable and comparable to the more conventional standing double leg countermovement jump [40] and frequently used for players' assessment (e.g. Sheppard et al. [36]). Finally, to obtain an indication of power, the jump height and body mass were used to estimate power, using the conversion equation ((60.7 x (jump height [cm])) + (45.3 x (body mass [kg])) – 2055) [34].

Training and assessment

The intervention took place in the off-season and following the completion of this age-group championship. The programme was designed and implemented by the team's coach as it would have normally happened, with the only difference being the addition of the assessment sessions (details below). It lasted for 15 weeks, which was the time-period available for that training phase. The training programme itself comprised of 2 plyometric sessions and 1 resistance training session per week. These sessions were embedded in the subjects' regular training; right after the resistance or plyometric sessions, the subjects were participating in their standard technical volleyball practice with their team. The assessment took place at four different time points across the 15 weeks; at pre-programme (T1) to obtain a baseline measurement, at the end of week 4 (first training block) (T2), at the end of week 12 (second training block) (T3), and at the end of week 15 (third training block and end of programme) (T4). T1 and T4 served as start and end measurements of the intervention, T2 was selected as a time point where improvements may be seen (e.g. Lehnert et al. [20] and Velickovic et al. [39] respectively).

Plyometric training

Prior to the initiation of the programme, the players completed two sessions similar to the sessions they would be completing for the programme. Although previously familiar with the required technique of the plyometric exercises, it was the first time the players would undergo a systematic plyometric training programme. Plyometric training volume was defined as the number of foot contacts and manipulated by increasing or decreasing that number. Plyometric intensity has been described and categorised extensively, with regards to the different type of exercises used [30]. The plyometric exercises used were 1) box jumps, 2) resisted rebound jumps (regular rebound jumps with an elastic band adapted to a belt of subjects' waist and stabilised on the floor), 3) hurdle jumps, and 4) from the 4th week onwards, depth jumps (35cm), and were executed double-legged as most of the jumps in volleyball are performed in that fashion. Therefore, intensity was manipulated by providing a target to aim for rebounding from a jump (e.g. increased or decreased hurdle height to jump over, or higher or lower point to touch).

The first 4 weeks were aiming to serve as introductory and preparative for the upcoming higher training volume, thus include a low-volume, moderate-intensity approach [37]. The subsequent 8 weeks, were aiming to increase the load progressively by increasing total number of jumps with only moderate increases in intensity. Thus, training volume was increasing by 10-20% every week (depending on accuracy of execution form) [37]. In the final three weeks, there was a significant increase in exercises intensity and a decrease in the total number of jumps. Weekly training sessions were alternated between a "heavy" session with the second one set at 60%-80% volume of the previous one. An overview of the plyometric training programme volume can be seen in Figure 1.

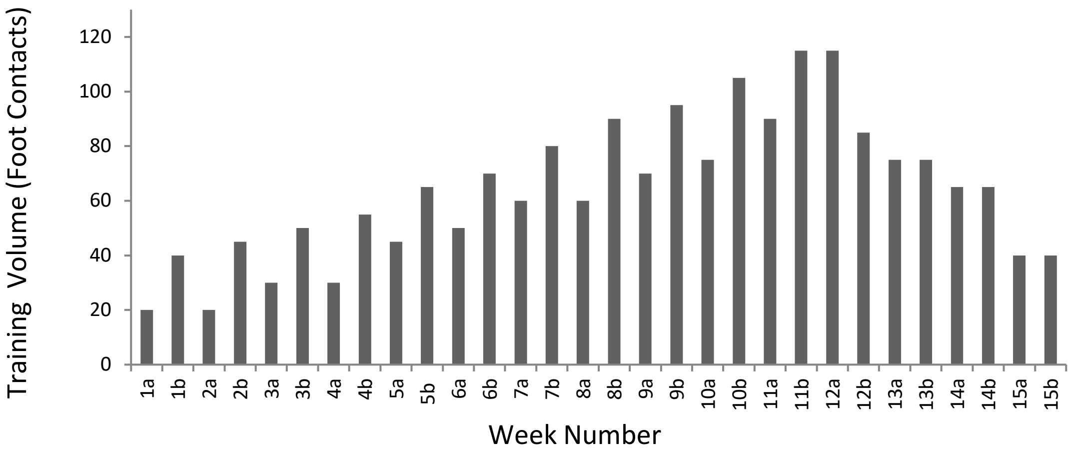

Figure 1A. Plyometric training volume (calculated as number of foot contacts) per session per week of the 15-week programme. a: first session of the week, b: second session of the week.

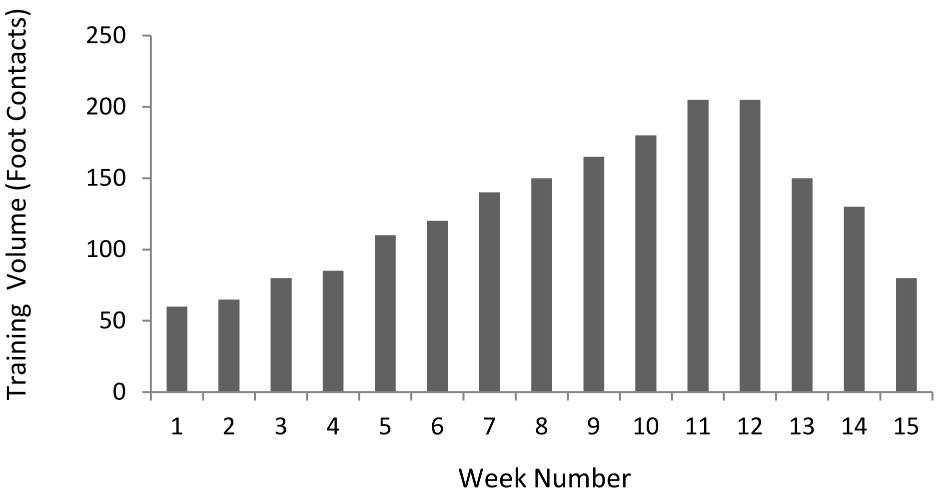

Figure 1B. Plyometric training volume (sum of both weekly sessions) per week of the 15-week programme.

Resistance training

Free weights were used for the resistance training while the squat, power clean and loaded single leg step-up exercises were utilised as some of the most functional multi-joint exercises for the volleyball player. The initial load was determined as the load the athlete was able to lift and complete, without any loss of form, the prescribed sets and repetitions but no more. To ensure the appropriate load that would enable and reflect strength increases, the load used was increased when an athlete was able to complete at least two more repetitions in addition to the prescribed sets and repetitions in the last set for two consecutive workouts [2].

Resistance training was set once a week. There was a progressive increase of the training volume (calculated as load (kg) x set (number of) x repetitions (number of)) until week 9. From week 9 there was a gradual decrease in volume (in line with the increase in plyometric volume) until week 12. Finally, the last three weeks (12-15) were used for tapering, similar to the plyometric programme. An overview of the resistance training programme volume can be seen in Figure 2, while an overview of the plyometric and resistance training volume interaction can be seen in Figure 3.

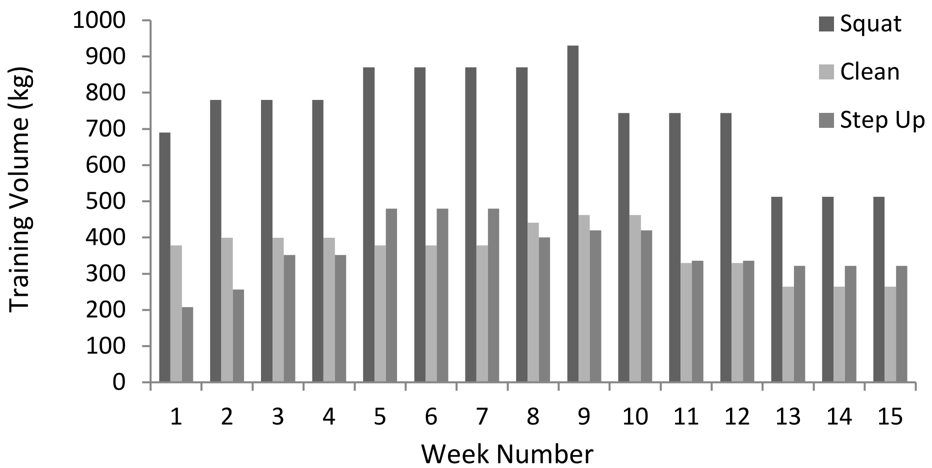

Figure 2A. Resistance training volume (calculated as load x sets x repetitions) per exercise per week of the 15-week programme.

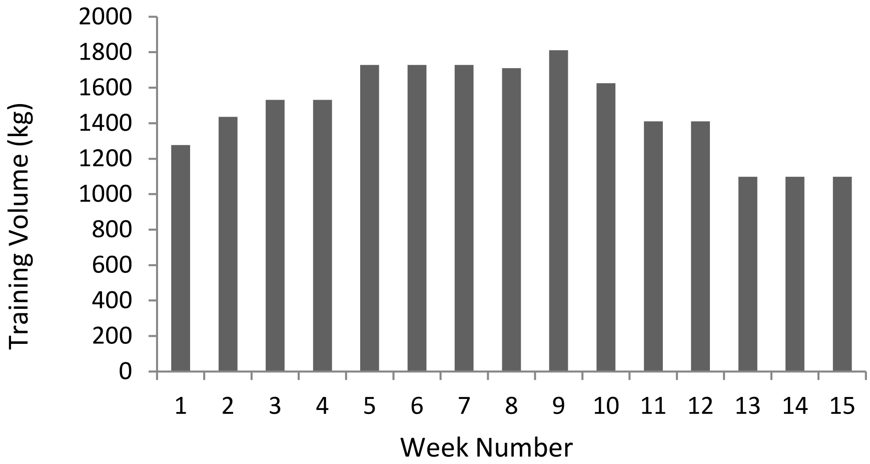

Figure 2B. Resistance training volume (sum of all exercises) per week of the 15-week programme.

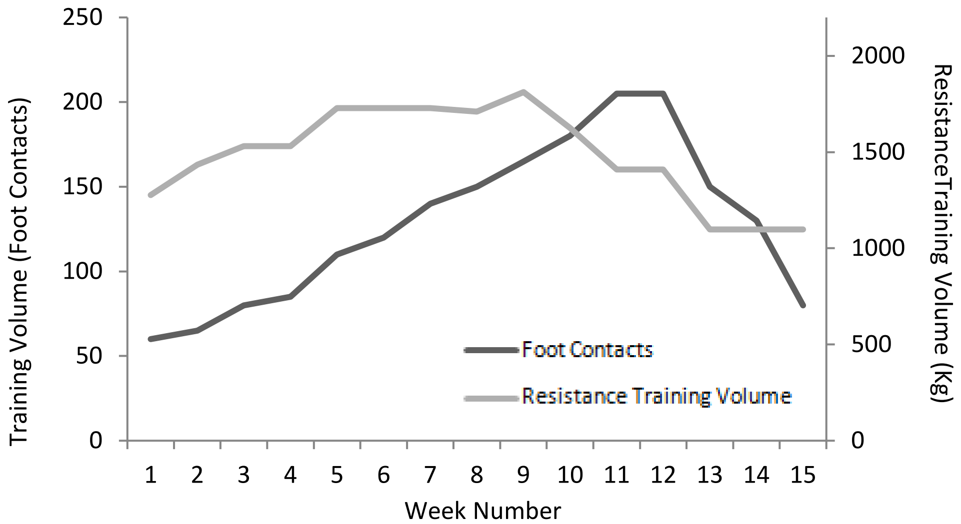

Figure 3. Overview of plyometric and resistance training volume over the 15 weeks of the intervention.

Data analyses

As some data points were missing (<10% of the overall sample and no more than 10% at any time point), the Markov Chain Monte-Carlo method was used to replace the missing values and avoid excluding pairwise comparisons. The intraclass correlation (ICC; an indication of agreement between trials), the typical error (TE; an indication of the error expected from measurement to measurement) and smallest worthwhile change

(SWC; smallest value one should consider as an actual improvement/worsening at follow-up measurement) result of jump height data were calculated [18]. ICC was calculated as 1- (TE^2 / mean between-subject standard deviation between trials), TE was calculated as standard deviation of the change scores between trials / square root of 2, and SWC as 0.3 x within-subject SD. Data was collected the same way as described above and from two time points prior to commencement of the intervention.

Subsequently, jump height and leg power data was checked for normality of distribution. As that was not confirmed and due to the relatively small sample size, a non-parametric approach was used or the statistical approach. Friedman's test was used to examine for differences across all time points, followed by Wilcoxon pairwise comparisons, with Holm-Bonferroni correction applied. For significant pairwise comparisons, non-parametric effect size (Cohen's r; ES) was calculated and interpreted as as small, moderate and large for values of 0.1, 0.3 and 0.5 respectively [14]. Data is presented as mean ± SD. Alpha level was set at 0.05 for all comparisons. Data processing was conducted with commercially available software (SPSS v25, IBM Systems, Chicago, USA).

Results

Reliability testing yielded ICC = 0.980, TE = 1.2cm and SWC = 2.2cm for the vertical jump height, indicating good reliability of the test while providing a 'benchmark' improvement to assist with interpretation of the results.

Jump height was significantly different across the four collection time points ($\chi^2(2)$ = 22.3, p = 0.001). Pairwise comparisons revealed that T1 and T2 were not significantly different between them but all other comparisons were. Leg power had a similar pattern, with a significant overall difference ($\chi^2(2)$ = 21.7, p = 0.001), T1 with T2 being not different but all other pairwise comparisons being significant different between them. All descriptive data, with p values and ES are presented in Table 1.

Table 1. Jump height (cm) and Power (W) results at all time points. Data is given for each time point (filled cells) and are presented as mean ± SD. T1, pre-programme; T2, end of week 4 (first training block); T3, end of week 12 (second training block); T4, end of week 15 (third training block and end of programme). Significance (corrected p value) and effect size (ES) are provided for each pairwise comparison. *denotes significant difference for the relevant comparison

Jump height (cm)				
	T1	T2	T3	T4
T1	46.4 ± 7.0	p = 0.786 ES = 0.09	p = 0.033* ES = 0.81	p = 0.025* ES = 0.89
T2		46.3 ± 6.5	p = 0.034* ES = 0.73	p = 0.025* ES = 0.89
T3			48.4 ± 6.7	p = 0.34 ES = 0.75
T4				50.5 ±7.8
Power (W)				
	T1	T2	T3	T4
T1	3639 ± 461	p = 0.768 ES = 0.09	p = 0.045* ES = 0.77	p = 0.025* ES = 0.89
T2		3636 ± 411	p = 0.045* ES = 0.66	p = 0.025* ES = 0.89
T3			3752 ± 457	p = 0.045* ES = 0.75
T4				3875 ± 484

Discussion

The aims of the project were to examine benefits of an off-season conditioning training programme with focus on plyometric training, in a pragmatic fashion, while following basic plyometric training principles for adolescent players. Our results show that the 15-week training programme used here can be effective in increasing the vertical jump height of female adolescent volleyball players.

The novelty of the present study lies in the practice-orientated experimental approach and the population used. In addition, the training programme was developed with the overall training approach in mind, rather than a ‘standalone’ training. Although training of technical and tactical aspects of the game takes place predominantly in-season, off-season still involves some such aspects. The suggested programme allowed for sport-specific conditioning training to take place during off-season training.

It is perhaps of importance to discuss the SWC briefly, and its relation to TE, prior to interpreting the results. SWC represents the smallest value beyond which we can be confident that a true change in performance has occurred [18]. It offers additional information to statistical significance, as the latter may still be present even if the magnitude of the change is not large enough to be meaningful. Essentially, it provides a criterion in assisting the interpretation of the results while allowing standardization and comparison with other studies, representing a key criterion in sport science for assessing changes in performance [31]. For example, Gabbet and Georgieff [16] utilised this concept to assess the sensitivity of a skill assessment for junior volleyball players. As TE refers to the measurement error of the test, it follows that for a performance assessment to be useful, TE must be smaller than the SWC. Our initial vertical jump comparisons showed that the TE (1.2cm) was indeed smaller than the SWC (2.2cm), suggesting the test would be sensitive enough to detect any real changes in performance.

The findings of the present study showed that the first training block (weeks 1-4) did not significantly affect jumping performance or power. The second training block (weeks 4-12), however, did result in a significant improvement both in jump height and power. That improvement (2cm, 4.3%) although greater than the TE and with a very large ES, was just below the expected SWC and, therefore, unlikely to have been of significantly large magnitude to reflect a true performance improvement. The final measurement point, nonetheless, showed both significance as well as a change (4.1cm, 8.8%) larger than the SWC. Power followed an identical pattern. As such, it appears that the designed programme was able to significantly improve the vertical jumping of female youth volleyball players.

Previous studies examining related training programmes in young female volleyball players, have also reported increases in performance albeit with mixed results in terms of the improvement magnitude. For example, Cancaya et al. [7] reported a 2.2cm (6.5%, ES = 0.45) vertical jump height increases obtained from Bosco Test at week 4 of a 6-week plyometric-only training programme with 15 year old female competitive volleyball players. In another plyometric-only training programme, Lehnert et al.[36] reported increases of 1.3cm (3.2%, ES = 0.22) in the vertical jump with approach after 4weeks of an 8-week programme with ~15 year old female volleyball players; unfortunately, no data was provided for the end of the programme. Pereira et al. [29] using ~14 year old female competitive volleyball players and a plyometric-only training programme, reported countermovement jump increases measured with a jump mat of 5.4cm (20.1, ES = 0.76). Finally, Velickovic et al. [39] reported increases of 4.98cm (20.1%; no SD provided for ES calculation) following a 12-week plyometric-only programme in 14-16 year old female volleyball players. Although plyometric-only studies as the above provide a useful insight into this training modality's effect on young female volleyball players, plyometric training was not intended as a 'stand-alone' training modality, but combined with other forms [6]. When a 6-week multicomponent neuromuscular training programme [26] was employed with ~15 years old female competitive volleyball players, vertical jump height (measured with a Vertec Jump system) improved by 1.4cm (3.5%, ES = 0.24). The different vertical jump types (e.g. countermovement with or without approach), measurement methods (e.g. Vertec, jump mat), training modalities (e.g. plyometric-only, combined) and length of the training programmes (e.g. 4 weeks, 8 weeks, 12 weeks) employed in the studies above, pose considerable difficulties in comparing the effectiveness of the present programme. The 4.1cm (8.8%, ES = 0.89) improvement at the end of the 15-week combined training programme in the present study, appears to compares favourably with the results reported in the experimental studies above. The difficulty in this comparison reinforces the need for further research in the area [28].

Plyometric training has been long established to improve the stretch-shortening cycle movement, resulting in increased power generation (e.g. Malisoux et al. [22]) and improved vertical jump height [23]. In female volleyball players, a plyometric training programme based on countermovement jumps training was more effective than drop jump training attributed to the specificity of the countermovement jump movement to sport [32], while Sheppard et al. [35] showed that the ability to tolerate higher stretch-shortening loads is critical to volleyball jumping-associated performance. Other mechanisms have also been suggested, such as the duration the muscle is in an active state [4, 5]. In support of this argument, Balasas et al. [3] reported improvements in both squat jump and countermovement jump height following beach volleyball training, which was not associated with increased pre-stretch augmentation. Further, Esformes and Bampouras [10] showed that a deeper squat as a conditioning contraction resulted in higher subsequent jump height, attributed to higher activation of the working muscles. It is not possible to identify the mechanisms responsible for the change seen in the present study, as in the absence of other measurements, e.g. squat jumps (for elasticity measures [3]) or kinematic measures (for countermovement depth [10]) any suggestion would be speculative. The mechanistic explanation (e.g. whether the difference was induced by increased active state, deeper countermovement depth due to ability of tolerating increased load, or some interaction of the two), however, is of no consequence to the aims of the study. Additional measures or tests would impeach on the practicality not only of the assessment but also of the analysis such an assessment would require. As the vertical jump described above provides reliable and sensitive data to the changes, with specificity to the sport, we posit that this simple measure is sufficient to offer an easily implemented measurement that can be relied upon to indicate improvement.

The need for a control group in single group, pre-post studies to increase internal validity is well established, and an acknowledged limitation of the present study. Training studies of longer durations are typically hard to design experimentally due to e.g. difficulty in finding a matching control group (e.g. Balasas et al. [3]). There are, on the other hand, certain benefits for studies that utilise a ‘natural experiment’ approach, as the point of interest happens without the researcher manipulating the intervention. These studies are closer to the coaches understanding and interest of what would normally happen with their team, and can address the gap between research and practice more effectively [17], fitting the study’s aspiration. In any case, the large effect sizes obtained as well as the magnitudes of improvement being greater than SWC and in line with published literature, support with relative confidence that the results seen are not coincidental. The use of a control group in future studies, however, will provide a more robust verification of the present findings. In addition, monitoring of internal training load through simple means such as session RPE as well as external load, will provide a more accurate picture of the training stress and allow better programme design and adjustment (41).

In conclusion, we have presented a pragmatic approach for implementing a plyometric conditioning programme during 15-week in the off-season leading to the competition phase of adolescent female volleyball players. The programme resulted in considerable vertical jump height and power increases, suggesting it is feasible to achieve such gains, thus increasing the chances of successful game performance. Based on these findings, volleyball coaches are encouraged to more effectively utilise off-season as a conditioning opportunity, assisting in better preparation of the players as well as allow more time to focus on the tactical elements of the game in-season.

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