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Original Article

THE EFFECT OF PLYOMETRIC TRAINING ON VERTICAL JUMP PERFORMANCE IN YOUNG BASKETBALL ATHLETES

O EFEITO DO TREINAMENTO PLIOMÉTRICO NO DESEMPENHO DO SALTO VERTICAL EM ATLETAS JOVENS DE BASQUETE

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RESUMO
Este estudo investigou o efeito do treinamento pliométrico (TP) no salto vertical em atletas jovens de basquete. Participaram 39 atletas, divididos em dois grupos experimentais (masculino - GEM e feminino - GEF) e dois grupos controle (masculino - GCM e feminino - GCF). O aplicativo *My Jump* quantificou a altura do salto a partir do tempo de voo. Para análise dos dados utilizou-se anova de medidas repetidas, tamanho de efeito de Cohen (TE) e a inferência baseada na magnitude, com nível de significância (p≤ 0,05). Os resultados indicam que o GEM e GCM apresentaram melhoras significativas no countermovement jump (CMJ) e squart jump (SJ). O GEF e GCF apresentaram diferenças significativas no SJ com efeito de interação, no CMJ apenas o GEF apresentou melhoras com efeito de interação. No TE, o GEM apresentou maiores efeitos no CMJ e SJ quando comparado ao GCM, no GEF, o TE foi maior somente no CMJ em relação ao GCF. As respostas qualitativas mostraram que o TP é provavelmente benéfico no GEM, já no GEF, mostrou que é provavelmente benéfico no SJ e muito provavelmente benéfico no CMJ. Conclui-se que o TP promoveu efeitos positivos no GEM e GEF, tanto no CMJ quanto no SJ. Nos grupos controles, ambos obtiveram melhorias significativas no SJ, porém no CMJ, somente o GCM apresentou aumento. Ademais, os resultados foram maiores no GEM e GEF em comparação com o GCM e GCF. Assim, o TP é indicado para potencializar o salto vertical em atletas jovens de basquete.
Palavras-chave: Exercício. Adolescente. Desempenho atlético. Esportes.

ABSTRACT
This study investigated the effect of plyometric training (PT) on vertical jump in young basketball athletes. A total of 39 athletes were divided into two experimental groups (male – MEG and female – FEG) and two control groups (male – MCG and female – FCG). The My Jump app quantified jump height from flight time. Data analysis relied on repeated measures ANOVA, Cohen's effect size (ES) and magnitude-based inference, with a level of significance of p≤ 0.05. Results showed that the MEG and the MCG obtained significant improvements in the countermovement jump (CMJ) and in the squat jump (SJ). The FEG and the FCG presented significant differences in the SJ, with interaction effect; as for the CMJ, only the FEG showed improvements with interaction effect. Concerning ES, the MEG showed greater effects in the CMJ and in the SJ compared to the MCG; within the FEG, the ES was greater only for the CMJ in comparison with the FCG. Qualitative responses showed that PT is likely beneficial for the MEG, whereas for the FEG it is likely beneficial in the SJ, and very likely beneficial in the CMJ. It is concluded that PT brought about positive effects on the MEG and on the FEG, both in the CMJ and in the SJ. In the control groups, both obtained significant improvements in the SJ, but only the MCG showed an improvement in the CMJ. Furthermore, results were better in the MEG and in the FEG compared to the MGC and to the FCG. Thus, PT is suitable for vertical jump enhancement in young basketball athletes.
Keywords: Exercise. Adolescent. Athletic performance. Sports.

Introduction

Basketball is a sport characterized by acyclic movements and intermittent context, involving highly intense and short-distance actions interspersed with brief rest intervals[1,2]. It is a modality with anaerobic prevalence, requiring fundamentals of an explosive nature, as well as the need for jumping, a very important motor skill directly associated with better sports performances[3].

Vertical jump in basketball is very present in specific skills, such as rebounding, shooting and blocking; a high number of jumps is performed during the game, making increased performance of the jumping ability a fundamental requirement to achieve success in basketball[2,4]. The training methods used by coaching staffs for vertical jump development include plyometric training (PT), widely adopted in team sports to promote the development of physical capacities in a variety of age groups, e.g., young athletes[5,6]. PT consists of jump exercises, which are actions involving the stretch-shortening cycle, a mechanism that happens when the muscle that is working switches from an eccentric action to a fast concentric action[7,8].

Sports Science points in the direction that PT is one of the main strategies used in the sports environment to optimize the vertical jump, due to its methodological ease of application, as well as its extremely low cost[9]. However, this evidence needs to be confirmed in competitive teams made up of young athletes, and this is the main justification for the present investigation. In addition, as far as the authors know, this is the first study to use the My Jump tool to assess vertical jump in a research with experimental design. Thus, the objective of this study is to investigate the effect of six weeks of a PT program on vertical jump in young basketball athletes.

Methods

Participants

Thirty-nine young athletes playing in a basketball team participated in this study; they were selected in a non-probabilistic manner, 16 of whom were male, and 23, female (Table 1). The inclusion criteria adopted were: being associated with the Pernambuco Basketball Federation [*Federação Pernambucana de Basquete*] (FPB), having at least one year of experience with basketball training, and presenting no muscle injuries or issues that prevented one from performing the activities with as much effort as possible. The exclusion criteria were: failing to attend 75% of the training sessions, missing the applied assessments, or injuring oneself during the application period of the training program. Two athletes were excluded due to injuries, and three, for missing more than 25% of the training sessions. One week before the tests were run, the athletes and their legal guardians were informed about the risks and benefits of the study, besides signing an Informed Consent form (ICF) and an Informed Assent Form (IAF), respectively. The study was approved by the Ethics Committee on Research Involving Humans of the Federal University of Pernambuco – Ethics Research Committee of the Federal University of Pernambuco's Health Sciences Center – under legal opinion No 2385105.

Table 1. Participants' descriptive data

	Experimental (n=17)		Control (n=17)	
	Male (n=6)	Female (n=11)	Male (n=7)	Female (n=10)
Age (years)	15.83 ± 0.75	14.45 ± 0.69	15.43 ± 1.13	15.30 ± 1.16
Height (meters)	1.83 ± 0.07	1.60 ± 0.07	1.74 ± 0.13	1.63 ± 0.08
Body mass (kg)	70.78 ± 11.83	53.72 ± 9.01	72.94 ± 24.13	59.98 ± 16.74
BMI (kg/m²)	21.65 ± 3.32	22.12 ± 3.95	22.21 ± 3.85	21.86± 3.84
WTF (days)	3.00 ± 0.00	3.00 ± 0.00	3.00 ± 0.00	3.00 ± 0.00

Note: WTF = Weekly training frequency
Source: The authors

Study Design

This study is of a descriptive nature and has an experimental design. It was carried out during the training pre-season of the teams over 8 weeks. In the first week, the athletes were subjected to a familiarization with the PT and with the vertical jump test, by means of two types of jump: the squat jump (SJ) and the countermovement jump (CMJ). The training sessions altogether lasted 6 weeks, starting in the second week and ending in the seventh week. In the eighth week, the athletes had their vertical jumps reevaluated through SJ and CMJ. The young players were randomly divided into four groups: two experimental groups and two control groups. The experimental group was divided into males (MEG) and females (FEG); both underwent PT and continued with their regular basketball training routine. The other two groups were the control – males (MCG) and females (FCG) –; they did not change their regular basketball training routine, which consisted of technical-tactical training. All athletes were instructed not to perform any training other than that proposed.

Vertical Jump Assessment

To determine the height of the vertical jump, a protocol that assesses flight time using video recording was adopted, identifying the athlete's takeoff and landing frame, thus providing the height of the vertical jump through this equation: $h = t^2 \times 1.2262510$. The assessment instrument was an iPhone 6s application, My Jump (Apple Inc., USA), which is part of the iOS operating system, uses the XCode software (5.0.5 for Mac OSX 10.9.2) and the Objective-C language, and is capable of recording at 240 Hz, with a quality of 720p[11,12]. To shoot the jumps, the evaluator stood 1.5 meters away from the athlete, focusing the shooting on the feet of the individual being evaluated. Taking into account other vertical jump assessment instruments, My Jump is an important tool due to its low cost, easy applicability and portability[13,14]. For the SJ, the athletes started from a static position, with their knees flexed at an angle of approximately 90 degrees. For the CMJ, they started from an upright and static position; subsequently, they performed an acceleration against their own center of gravity and a knee flexion at approximately 90°. Both jumps must be executed with the hands on the hips, just as described by Pupo, Detanico and Santos[15]. During the evaluation, the athletes performed 3 SJs, then 3 CMJs, with a 2-minute recovery interval between jumps; the highest height in centimeters (cm) between jumps was used for analysis, and all athletes were instructed to jump to the maximum of their individual capacity.

Training Program

The PT program started from a standardized warm-up, which included running at increasing speed and guided by verbal stimuli, as well as dynamic stretches lasting approximately 10 minutes. The PT was applied on two non-consecutive weekdays for 6 weeks (Mondays and Wednesdays). Training volume was defined based on number of jumps, which was gradually raised each week (Table 2). In all training sessions, the jump exercises progressed in intensity and complexity. Intensity was assessed from a technique-based jump progression (exercise complexity). PT details are described in Table 2. Rests between jumps and sets comprehended 30 and 120 seconds, respectively; there was no rest between jumps, except for the group jump, in which the velocity of performance was the focus. The athletes were instructed on the mechanics of the jumps and encouraged to jump with as much effort as possible; all jumps were executed under the same environment and floor conditions. The basketball training occurred after the application of the PT program and consisted of technical-tactical training aimed at working on small-sided games, attack moves and individual defense. This training was held three times a week (Mondays, Wednesdays and Fridays).

Table 2. PT program

Jump exercises	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Vertical (CMJ)	2x10	1x10	1x15	1x10		2x10
Lateral	2x10	1x10	1x15		1x10	
Horizontal	1x10	2x10	2x10	2x10	2x10	2x10
With knee raise		4x5		2x10	2x10	
With alternating lunges			4x5			2x10
Forward and consecutive				6x5		
Vertical unilateral					4x5	4x5
Lateral unilateral					4x5	4x5
Total # of jumps	50	60	70	80	90	100

Note: 2x10 indicates 2 sets and 10 repetitions, CMJ – countermovement jump
Source: The authors

Statistical Analysis

Data are presented as means with standard deviation (SD). A repeated measures ANOVA was used to compare the results of the tests prior to the training with the results afterwards. The percentage of variation (Δ%) was determined through the following equation: Δ% = ([post-intervention – pre-intervention]/pre-intervention) x 100. In addition, Cohen's effect size was determined for the statistical differences identified. Effect sizes (ES) whose values were 0.2, 0.5 and 0.8 were considered as representing small, medium and big differences, respectively. Besides this test, for each variable, percentage differences in the change scores between the EG and the CG from the pre- to the post-test period were calculated together with 90% confidence intervals. The likelihoods of differences in performance being better/bigger (that is, bigger than the smallest valid change [0.2 multiplied by the SD between subjects, based on Cohen's d principle]) and similar or worse/smaller were calculated. The quantitative likelihoods of beneficial/better effects and harmful/poorer effects were assessed qualitatively as follows: < 1%, almost certainly not; 1% to 5%, very unlikely; 5% to 25%, unlikely; 25% to 75%, possibly; 75% to 95%, likely; 95% to 99%, very likely; and > 99%, almost certainly[16]. A substantial effect was established at > 75%. If the likelihoods of having beneficial/better and harmful/poorer performances were both > 5%, the actual difference would be deemed unclear. Significance was established at an α level of 0.05. All statistical analyses were run on the SPSS statistical package for Macintosh (version 21.0, Chicago, IL, USA).

Results

Table 3 displays comparison results for CMJ and SJ between the CG and the EG for both sexes. Said results showed that everyone in the male groups improved their CMJ ($F(2.12) = 11.11$, $p = 0.007$) and SJ ($F(2.12) = 11.07$, $p = 0.007$), but with no interaction effect for either CMJ ($F(2.12) = 4.47$, $p = 0.58$) or SJ ($F(2.12) = 3.18$, $p = 0.1$). Among females, the SJ improved in both groups ($F(2.20) = 8.43$, $p = 0.009$), with interaction effect ($F(2.20) = 4.29$, $p = 0.05$). For the CMJ, only the EG showed improvements with interaction effect ($F(2.20) = 8.90$, $p = 0.008$).

In the Δ% analysis, the FEG showed a variation of 13.06 and 10.75 for SJ and CMJ, respectively. The FCG, in its turn, presented a Δ% of -3.01 for CMJ, and 2.58 for SJ. In the MEG, Δ% values were 11.98 and 10.98 for SJ and CMJ, respectively. In the MCG, the SJ presented a Δ% of 3.71, and the CMJ, a Δ% of 2.50. As for the chances of the PT program being efficient, there is a likely possibility of the training being efficient for the male group when it comes to both the SJ and the CMJ. In the female group, the PT showed a likely chance of improving the SJ and a very likely chance of improving the CMJ.

Table 3. Effect of 6 training weeks on SJ and CMJ

Test	Con	Pre-intervention	Post-intervention	ES	MBI (EG vs CG)	Qualitative Response (QR)
			Male			
SJ	CG	29.64 + 5.80	30.74 + 5.77*	0.19		
(cm)	EG	30.45 + 7.82	34.10 + 6.76*	0.54	81/19/01	Likely
CMJ	CG	31.55 + 6.26	32.34 + 6.88*	0.12		
(cm)	EG	32.14 + 7.89	35.67 + 8.11*	0.48	84/15/01	Likely
			Female			
SJ	CG	21.31 + 4.53	21.86 + 3.65*	0.14		
(cm)	EG	25.48 + 5.32	28.81+4.40*†	0.11	90/10/01	Likely
CMJ	CG	23.23 + 4.45	22.53 + 4.37	0.17		
(cm)	EG	26.88 + 5.51	29.77+5.09*†	0.57	98/02/00	Very likely

Note: Con: condition; CG: control group; EG: experimental group; SJ: squat jump; CMJ: countermovement jump; ES = intra-group effect size; MBI: magnitude-based inference; *significantly higher than pre-test; † significantly higher than CG
Source: The authors

Discussion

The present study investigated the effect of a 6-week PT on vertical jump in young basketball athletes. The findings show that both the MEG and the MCG improved their SJ and CMJ. Among females, there was improvement in both groups for SJ; the EG's improvement was significantly greater than that of the CG, whereas the CMJ showed positive significance only in the EG.

Indeed, studies have shown the influence of PT on vertical jump in young athletes[5,17]. The present findings among females are in line with a study conducted by Idrizovic et al.[18], who investigated the effect of an 8-week PT on young volleyball athletes; their results showed that the group subjected to PT obtained superior effects in the CMJ compared to the control group, presenting "almost certainly positive" qualitative descriptors. Post hoc analyses indicated that the group that underwent PT obtained better effects compared to the control group. Likewise, McCormick et al.[19] verified the effectiveness of PT for CMJ among young basketball athletes. In said investigation, female athletes were divided into two groups – one that underwent PT in the sagittal plane (SPP), and one that underwent PT in the frontal plane (FPP); it found that both groups improved their CMJ performance CMJ after the PT, but the SPP group, in comparison with the FPP, showed a significant improvement in the CMJ, with a percentage increase of 10.3% and 3.8%, respectively, from the pre-intervention to the post-intervention period, thus showing that PT were effective in both groups.

The findings of the present study in the FEG for both SJ and CMJ were similar to those reported by Attene et al.[20], who compared the effects of PT with basketball training over 6 weeks on vertical jump among young female basketball players (age of 14.9 ± 0.9 years and body weight of 54.0 ± 8.7 kg). The study showed that the group subjected to PT obtained significantly greater gains for the parameters of the SJ compared to those of the CMJ, presenting a percentage change before and after training of 15.4% and 11.3% in the SJ and the CMJ, respectively. There still are few studies in the scientific literature addressing PT in young athletes, especially when investigating its effects on females, so further research is needed to clarify this influence in this population.

Corroborating the findings for males, the effect of a 6-week PT on vertical jump in young basketball athletes was investigated; they were divided into 2 groups, one that underwent PT (EG) and another one that only played basketball (CG), with the EG obtaining improvements compared to the CG[21]. The same study observed that the EG improved their vertical jump by 24.1%. Results from a previous study also revealed a significant improvement of 23% in the vertical jump after a 6-week PT among semi-professional basketball athletes[22]. PT is also believed to be important in other sports, such as football, in which Chaabene and Negra[23] investigated and compared the effect of high-volume plyometric training (HPT) and low-volume plyometric training (LPT) in pre-pubertal players. The authors evidenced that 8 weeks of PT promoted significant gains in SJ and CMJ for both training types, showing that PT provides significantly equal gains at both intensities, having a direct influence on the athlete's sports performance.

Basketball training, due to its specificity, can contribute to improving vertical jump performance, since the execution of technical gestures requires the use of this skill, which is constantly performed during training[2,4]. Indeed, this scenario was presented both by the FCG in the SJ (Δ% = 2.58) and by the MCG in the SJ (Δ% = 3.71) and in the CMJ (Δ% = 2.50); however, the ES was small for both groups and jumps, which requires caution before trying to generalize the results. Nonetheless, it is possible to verify that regular basketball training combined with PT provided greater effects both on the FEG for SJ (Δ% = 13.06; QR = likely) and for CMJ (Δ% = 10.75; QR = very likely) and on the MEG for SJ (Δ% = 11.98; QR = likely) and for CMJ (Δ% = 10.98; RQ = likely). The enhancement of the stretch-shortening cycle is believed to be a factor that can explain significant improvements in vertical jump performance. The development of this cycle happens from a better utilization of the elastic components of the muscles and of the stimuli of proprioceptive reflexes through plyometric exercises, resulting in several positive adaptations in the neuromuscular system, which are directly associated with improvements in vertical jump performance[24-26].

Investigations about the influence of PT on vertical jump in athletes of both sexes, in a variety of sports, are unanimous as to the quantitative improvement of this skill, even when these differences are not statistically significant, improving the athletes' performance[18-23].

The absence of a biological maturation assessment, the small number of participants, the impossibility of assessing internal load, sleep routine and diet, as well as controlling the environmental temperature are the limitations of this study. Further research on PT need to be conducted with young basketball players, especially to assess biological maturation and internal load control, as they are factors that have a direct influence on performance.

Conclusions

This study highlights that the six-week PT induced positive effects on CMJ and SJ in young basketball athletes. In SJ and CMJ, the MEG and the MCG showed statistically significant increases, with greater increases in the MEG. Among females, both the SJ and the CMJ showed statistically positive increases between the EG and the CG. In the SJ, both the FEG and the FCG improved significantly, whereas only the FEG showed improvements in the CMJ.

The qualitative responses showed that, within the MEG, PT is likely beneficial for both the SJ and the CMJ. Now, in the FEG, it is likely beneficial for the SJ and most likely beneficial for the CMJ.

In view of these results, it is possible to confirm the importance of applying PT to this age group, especially for types of training that seek to enhance the vertical jump.

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