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The Journal of Sports Medicine and Physical Fitness 2021 January;61(1):53-62
DOI: 10.23736/S0022-4707.20.11128-9

REVIEW
EXERCISE PHYSIOLOGY AND BIOMECHANICS

Tapering strategies applied to plyometric jump training: a systematic review with meta-analysis of randomized-controlled trials

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ABSTRACT

INTRODUCTION: The purpose of this systematic review was to analyze the effect of plyometric jump training (PJT) applied in conjunction with tapering strategies on the jump performance of team-sport athletes.
EVIDENCE ACQUISITION: The meta-analysis included: 1) randomized-controlled studies that incorporated a PJT program; 2) cohorts of team-sport athletes; 3) jump performance assessments; and 4) studies that incorporated a programmed taper. A systematic search was conducted in distinct electronic databases for relevant studies. Aside from jump performance, the extracted data included characteristics of the participants, PJT, and tapering. Means and standard deviations were used to calculate the effect sizes (ES). To assess the effects of moderator variables, subgroup analyses were performed. The statistical significance level was set as P<0.05.
EVIDENCE SYNTHESIS: From 7020 records initially identified, 14 studies were eligible for meta-analysis. Across all included studies, there was a moderate, significant improvement in jump performance (ES=0.73; P<0.001). Additionally, the subgroup analysis demonstrated that the duration and intensity of the taper and the volume of the PJT induced similar improvements in jump performance (P<0.01).
CONCLUSIONS: In summary, PJT interventions that included a programmed taper induced significant improvements in jump performance in team-sport athletes. These effects were observed after different tapering strategies in terms of volume, taper duration, and the type of PJT prescribed.

(*Cite this article as:* Ramirez-Campillo R, Pereira LA, Andrade DC, Méndez-Rebolledo G, de La Fuente CI, Castro-Sepulveda M, *et al.* Tapering strategies applied to plyometric jump training: a systematic review with meta-analysis of randomized-controlled trials. J Sports Med Phys Fitness 2021;61:53-62. DOI: 10.23736/S0022-4707.20.11128-9)

KEY WORDS: Athletes; Athletic performance; Plyometric exercise.

Plyometric jump training (PJT) is an effective method to improve a wide range of physical performance measures (*e.g.* jumping, sprinting, change of direction speed) in athletes from distinct sport disciplines.[1-4] PJT programs are commonly associated with jumping drills designed to optimize the stretch-shortening cycle (SSC).[5, 6] As previously demonstrated, jump exercises are able to induce enhanced neuromuscular (*e.g.* improved neural drive to agonist muscles) and mechanical properties (*e.g.* alterations to musculotendinous stiffness and architecture) of the involved tissues.[7, 8] Awareness of the beneficial effects derived from PJT may be related to the significant number of PJT-related publications, with a 25-fold increase between 2000 and 2017.[9] From the available literature, several training elements seem to have a crucial role in the benefits associated with PJT, such as total program duration, frequency, volume, intensity, exercise selection, training surface, and drill randomization.[9-11] A potentially relevant element of PJT programs, popularly termed “tapering” (*e.g.* programmed reduction in training loads close to competitions),[12] has been overlooked by the literature, which could be of great interest to practitioners and researchers.

Tapering is a popular strategy used by coaches of different sports before official competitions in an attempt to boost performance,[12] which may be achieved by modifying different aspects of the training content. The expected improvements in sport form may be related to distinct physiological and metabolic mechanisms, such as a more favorable anabolic milieu, improved histological or contractile characteristics of muscles, and increased neuromuscular efficiency.[12-14] For example, in endurance athletes, increases in different physiological markers (*e.g.* hemoglobin, hematocrit, and muscle oxidative capacities) and power capacity were observed after 5-21 days of a reduction in training volume of between 60 and 90%.[15] Similarly, in well-trained triathletes, a reduction in the volume-based load was associated with improvements in a 15-min cycling time trial.[16] Aside from volume-based strategies, intensity-based tapering during 7 days after 7 weeks of endurance training in male cyclists, revealed a tendency toward better 40-km time trial performance and other measures related to endurance capabilities (*e.g.* maximum oxygen consumption, power at ventilatory threshold, and muscle glycogen concentration).[17] Nonetheless, in the same study,[17] the athletes who followed a volume-based approach presented superior improvements in a series of physical and physiological measures when compared to intensity-based taper.[17] In fact, a meta-analysis indicated that a taper phase during which training volume is reduced (provided intensity is maintained) seems to be the most efficient strategy to maximize competitive performance in top-level athletes.[18]

Regardless of the selected strategy, it can be inferred that a preplanned taper would be relevant for an effective prescription of plyometrics. For example, in a 7-week study with male and female cross-country runners,[19] male athletes performed a progressive volume-based PJT, while females executed a PJT program using a progressive taper strategy. Overall, males demonstrated lower gains than females in the vast majority of measurements, along with possibly harmful effects on competitive times for males and beneficial for females. Likewise, an investigation by Cormie *et al*.[20] reported greater improvements in jumping ability after a 5-week PJT in participants who followed a tapering regime (compared to participants that completed the same intervention without following a taper scheme). From these findings it is plausible to assume that, during PJT, the application of programmed tapering approaches is an effective way to optimize sport performance.[17, 21-23]

Although the aforementioned studies suggest that tapering strategies can maximize increases in jump capacity when applied during PJT, to date, this issue has not been examined through a systematic review. Additionally, a recent PJT review[9] revealed that, from 242 studies, only 15.5% incorporated a taper scheme. On that basis, the effects of a taper as part of a PJT protocol need to be further and more comprehensively investigated. Therefore, the purpose of this systematic review was to analyze the effect of PJT applied in conjunction with tapering strategies on the jump performance of team-sport athletes.

Evidence acquisition

A systematic review and meta-analysis was conducted following the guidelines of the Cochrane Collaboration.[24] Findings were reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[25]

Eligibility criteria

Only peer-reviewed articles were considered for the meta-analysis. The *a-priori* inclusion criteria were as follows: 1) randomized-controlled studies incorporating a PJT program of at least 2 weeks duration, and that included lower-body jumping, bounding, or hopping actions that commonly utilize a prestretch or countermovement to incite the usage of the SSC.[9, 26, 27] The control group was an active-inactive matched group of participants not involved in PJT. Trials that included PJT combined with another intervention (co-intervention) were included when an active control group was included, as long as the PJT intervention was not simply an added load and comprised ≥50% of the intervention; 2) considering that the effect of a taper[18] as well as the effect of PJT[28] may vary according to the type of sport practiced, an additional inclusion criteria considered studies with cohorts of healthy team-sport athletes (with no restriction for age or sex); 3) a measure of jump performance,[27, 29] with a very high test-retest reliability;[30] and 4) studies that incorporated a taper (*i.e.* a reduction in the training load applied at the end of the training program)[9, 12] and provided all details about the implemented strategy.[18]

Cross-sectional investigations, reviews, or training-related studies not focusing on the effect of PJT exercise were excluded. In addition, articles of poor quality, based on a risk of bias analysis, were not considered for inclusion. Excluded criteria also comprised observational studies, investigations in which the PJT content was not clearly described, studies with no full-text available, case reports, and repeated-bout effect interventions. Finally, studies that were not published in English were not explored.

Information sources

A systematic search was conducted in the electronic databases PubMed, MEDLINE, Web of Science, and Scopus for relevant studies until August 1, 2019. Key words were collected through expert opinions, a systematic literature review, and controlled vocabulary (*e.g.* Medical Subject Headings: MeSH). Boolean search syntax using the operators “AND” and “OR” was applied. The words “ballistic,” “complex,” “explosive,” “force-velocity,” “plyometric,” “stretch-shortening cycle,” “jump,” “training,” “taper,” and “tapering” were used. After an initial search, accounts were created in the respective databases. Through these accounts, the lead investigator automatically received generated e-mails on updates regarding the search terms used. These updates were received on a daily basis (if available), and studies were eligible for inclusion until the initiation of manuscript preparation on October 15, 2019. Following the formal systematic searches, additional hand-searches were conducted. Grey literature sources (*e.g.* conference proceedings) were also considered if a full-text version was available. Lastly, the reference lists of included studies and previous reviews were examined to detect studies potentially eligible for inclusion.

Study selection

To select studies for inclusion, a review of all relevant article titles was conducted before an examination of their abstracts and, finally, of the full articles. The publications excluded, with the due reasons, were recorded.

Data collection process

Data were extracted from the included articles using a customized spreadsheet (Microsoft Excel, Microsoft Corporation, Redmond, WA, USA).

Data items

Aside from a measure of jump performance, extracted data also included the following information: the first author’s name, year of publication, country of the first author’s institution, quality of PJT treatment description, type of control, type of randomization, and number of participants per group. In addition, participants’ characteristics, previous experience with PJT, and competitive level were recorded. Regarding PJT elements, the data extracted considered the frequency, duration, and intensity level of the training, number of jumps completed, types of jump drills, the combination (if applicable) of PJT with another form of training type, resting time between sets, repetitions, number of sessions, jumping surface, training phase, and tapering strategy. Finally, potential limitations of the studies were also recorded for a more comprehensive qualitative analysis of the outcomes.

Risk of bias in individual studies

The Physiotherapy Evidence Database (PEDro) Scale[31, 32] was used to assess the risk of bias and methodological quality of the included studies. This scale evaluates internal study validity on a scale from 0 (high risk of bias) to 10 (low risk of bias). As in a similar previous PJT meta-analysis,[33] the quality of assessments was interpreted as follows: ≤3 points was considered poor quality, 4-5 points as moderate quality, and 6-10 points as high quality. If trials had already been assessed and listed on the PEDro database (or similar sources), those scores were adopted. Two independent reviewers (RRC-DA) performed this process and, in the event of a disagreement, a third reviewer checked the data and took the final decision. Agreement between reviewers was assessed using a kappa correlation for risk of bias. The agreement rate achieved was k=0.91.

Summary measures

Meta-analyses were conducted when at least three studies provided effect sizes (ES) for the jump performance outcome.[27, 34, 35] Means and standard deviations for a postintervention measure were used to calculate an ES (Cohen’s *d*). When data values from a study were not available, the corresponding author was contacted requesting information. When no response was obtained, software was used to obtain mean and standard deviation values from graphical data (GetData Graph Digitizer).

The inverse-variance random-effects model for meta-analyses was used as it allocates a proportionate weight to trials based on the size of their individual standard errors[36] and facilitates analysis while accounting for heterogeneity across studies.[37] This approach was used to better account for the inaccuracy in the estimate of between-study variance.[38] The ESs are represented by the standardized mean difference alongside 95% confidence intervals (CIs). The ESs were interpreted using the following thresholds proposed by Hopkins *et al*.[39] (<0.2: trivial; 0.2-0.6: small; >0.6-1.2: moderate; >1.2-2.0: large; >2.0-4.0: very large; >4.0: extremely large). All analyses were carried out using the Comprehensive Meta-Analysis program (version 2; Biostat, Englewood, NJ, USA).

Synthesis of results

The percentage of total variation across the studies due to heterogeneity[40] was used to calculate the I^2 statistic. This represents the proportion of effects that are due to heterogeneity as opposed to chance.[25] Low, moderate, and high levels of heterogeneity correspond to I^2 values of <25%, 25-75%, and >75%, respectively.[40, 41] The χ^2 test assesses if any observed differences in results are compatible with chance alone. A low P value, or a large χ^2 statistic relative to its degree of freedom, provide evidence of heterogeneity of intervention effects beyond those attributed to chance.[36]

Risk of bias across studies

The risk of bias across studies was assessed using the extended Egger's test.[42] Sensitivity analyses were conducted to assess the robustness of the summary estimates to determine if a particular study accounted for the heterogeneity.

Additional analyses

To assess the potential effects of moderator variables, subgroup analyses were performed. Using a random-effects model, the moderator variables total number of jumps, and taper magnitude and duration, were included in the analyses. Participants were divided using a median split.[43-45] Meta-analyses stratification by each of these factors was performed, with a P value of <0.05 considered as the threshold for statistical significance.

Evidence synthesis

Study selection

Figure 1 provides a graphical schematization of the study selection process. Through database searching, 7,020 records were initially identified and 70 PJT studies included taper, 34 studies included a randomized-controlled design, and of these, 14 included team-sport athletes and were eligible for meta-analysis,[11, 28, 46-57] comprising 22 experimental groups and 278 participants involved in PJT interventions.

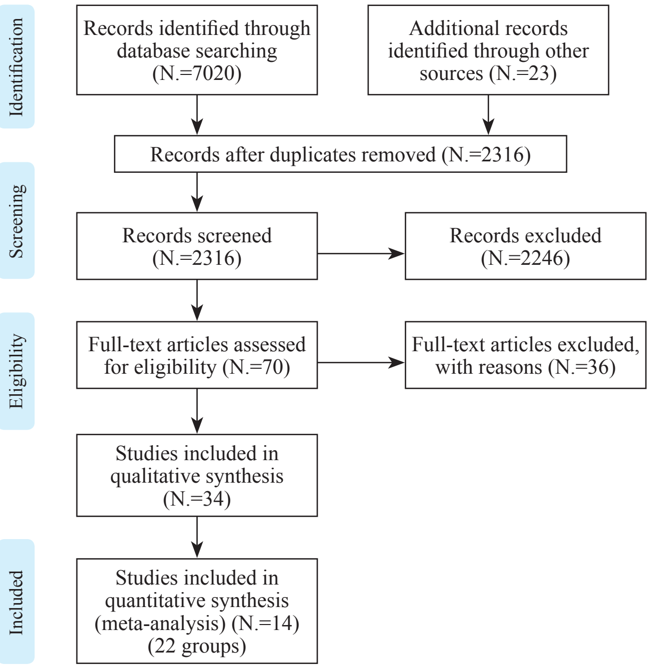

Figure 1.—Flow diagram of the study selection process.

Study characteristics

The characteristics of the participants and the programming parameters of the PJT interventions are displayed in Table I,[11, 28, 46-57] while the taper characteristics of the included studies are displayed in Table II.[11, 28, 46-57]

Risk of bias within studies

From the studies included in the meta-analysis, two achieved a quality assessment of 5 points, interpreted as moderate quality, while the other twelve achieved a quality assessment of 6-8 points, interpreted as high- quality (Table III).[11, 28, 46-57]

Results of individual studies and synthesis of results

Across all included studies, there was a moderate significant improvement in jump performance (ES=0.73 [95% CI: 0.45-1.02], Z=5.11, P<0.001) (Figure 2).[11, 28, 46-57] The relative weight of each study in the analysis varied between 2.8% and 6.7%, demonstrating an equilibrated weight dis-

TABLE I.—*Characteristics of jump training programs and of included study participants.*

Authors/References	N.	G	Age	Sport	Test	Freq	Weeks	Intensity	Total number of jumps	Surface	Training period
Ramirez-Campillo *et al.*[11]	25 (non-optimal)	M	13.9	Soccer	CMJ	2	7	Max	906	Grass	IS
	24 (optimal)		13.1								
Vlachopoulos *et al.*[28]	15	M	13.8	Soccer	CMJ	3 - 4	36	NR	8,880	Hard	NR
Chtara *et al.*[46]	10	M	13.6	Soccer	SLJ	2	6	NR	632	NR	IS
Hammami *et al.*[47]	14	M	16.1	Soccer	CMJ	2	8	NR	1,440	NR	IS
Hernandez *et al.*[48]	6 (randomized)	M	11	Basketball	CMJ	2	7	Max	1,044	Wood	IS
	7 (non-randomized)		10								
Kamalakkannan *et al.*[49]	12 (with weights)	NR	19	Volleyball	CMJA	3	12	NR	4,080	Water	NR
	12 (without weights)										
Makhlouf *et al.*[50]	21 (balance-jump)	M	11.1	Soccer	CMJ	2	8	Max	1,826	NR	NR
	20 (agility-jump)		11.3								
Poomsalood and Pakulanon[51]	5	M	19.6	Basketball	CMJA	2	4	Max	960	Court	NR
Ramirez-Campillo *et al.*[52]	8 (single surface)	M	12.9	Soccer	CMJ	2	8	Max	810	Grass	IS
	8 (combined surfaces)		12.1								
Ramirez-Campillo *et al.*[53]	12 (before soccer)	M	16.9	Soccer	CMJ	2	7	Max	1,424	Grass	IS
	14 (after soccer)		17.1								
Ramirez-Campillo *et al.*[54]	8 (1 session/week)	F	22.8	Soccer	CMJ	1	8	Max	810	Comb	IS
	8 (2 sessions/week)		21.4			2					
Sedano *et al.*[55]	10	F	22.8	Soccer	CMJ	3	12	Max	3,240	Synthetic	IS
Vaczi *et al.*[56]	12	M	21.9	Soccer	Drop CMJA	2	6	Max	925	NR	IS
Yanci *et al.*[57]	15 (2 sessions/week)	M	23.6	Futsal	CMJ	2	6	NR	564	NR	IS
	12 (1 session/week)		22.6			1					

CMJ: countermovement jump; CMJA: countermovement jump with arms; Comb: combined; F: female; Freq: frequency of training (days/week); G: gender; IS: in-season; M: male; Max: maximal; n: number of participants; NR: not reported; SLJ: standing long jump.

TABLE II.—*Taper characteristics of included studies.*

Authors/References	Number of jumps per week												Duration of the taper (days)		Decrease in training volume (%)	
	1	2	3	4	5	6	7	8	9	10	11	12	≤7	>7	≤40	>40
Ramirez-Campillo *et al.*[11] (non-optimal)	96	108	120	146	162	180	96						X			X
Ramirez-Campillo *et al.*[11] (optimal)	96	108	120	146	162	180	96						X			X
Vlachopoulos *et al.*[28]	2059 (weeks 1-12); 2416 (weeks 13-24); 2181 (weeks 25-36)[a]													X	X	
Chtara *et al.*[46]	160	184	216	240	264	200							X		X	
Hammami *et al.*[47]	210		240		136		136							X		X
Hernandez *et al.*[48] (randomized)	94	116	146	168	198	228	94						X			X
Hernandez *et al.*[48] (non-randomized)	94	116	146	168	198	228	94						X			X
Kamalakkannan *et al.*[49] (with weights)	432		576		684		732		912		792			X	X	
Kamalakkannan *et al.*[49] (without weights)	432		576		684		732		912		792			X	X	
Makhlouf *et al.*[50] (balance-jump)	80	200	240	300	96	360	450	100					X			X
Makhlouf *et al.*[50] (agility-jump)	80	200	240	300	96	360	450	100					X			X
Poomsalood and Pakulanon[51]	200	240	280	240									X		X	
Ramirez-Campillo *et al.*[52] (single surface)	80	80	100	100	120	120	140	70					X			X
Ramirez-Campillo *et al.*[52] (combined surfaces)	80	80	100	100	120	120	140	70					X			X
Ramirez-Campillo *et al.*[53] (before soccer)	148	176	224	232	260	288	96						X			X
Ramirez-Campillo *et al.*[53] (after soccer)	148	176	224	232	260	288	96						X			X
Ramirez-Campillo *et al.*[54] (1 session/week)	80	80	100	100	120	120	140	70					X			X
Ramirez-Campillo *et al.*[54] (2 sessions/week)	80	80	100	100	120	120	140	70					X			X
Sedano *et al.*[55]	240	270	210	270	300	240	200	330	270	330	360	300	X		X	
Vaczi *et al.*[56]	135	135	190	190	190	85	85							X		X
Yanci *et al.*[57] (2 sessions/week)	78	78	134	134	70	70								X		X
Yanci *et al.*[57] (1 session/week)	78	78	134	134	70	70								X		X

[a]the volume is the total per every 12-weeks period.

Table III.—*Physiotherapy Evidence Database (PEDro) scale ratings.*

	N. 1	N. 2	N. 3	N. 4	N. 5	N. 6	N. 7	N. 8	N. 9	N. 10	N. 11	Total score
Ramirez-Campillo *et al.*[11]	1	1	1	1	0	0	1	1	1	1	1	8
Vlachopoulos *et al.*[28]	1	1	1	1	0	0	0	1	1	1	1	7
Chtara *et al.*[46]	1	1	0	1	0	0	0	1	1	1	1	6
Hammami *et al.*[47]	1	1	0	1	0	0	0	1	1	1	1	6
Hernandez *et al.*[48]	1	1	1	1	0	0	1	1	1	1	1	8
Kamalakkannan *et al.*[49]	1	1	0	1	0	0	0	1	1	1	1	6
Makhlouf *et al.*[50]	1	1	0	1	0	0	0	1	1	1	1	6
Poomsalood and Pakulanon[51]	1	1	0	1	0	0	0	1	1	1	1	6
Ramirez-Campillo *et al.*[52]	1	1	1	1	0	0	1	0	1	1	1	7
Ramirez-Campillo *et al.*[53]	1	1	1	1	0	0	1	1	1	1	1	8
Ramirez-Campillo *et al.*[54]	1	1	1	1	0	0	1	0	0	1	1	6
Sedano *et al.*[55]	1	1	0	1	0	0	0	1	0	1	1	5
Vaczi *et al.*[56]	1	1	0	1	0	0	0	1	1	1	1	6
Yanci *et al.*[57]	1	1	0	0	0	0	0	1	1	1	1	5

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z value	P value
Chtara *et al.*	1.729	0.524	0.275	0.702	2.757	3.299	0.001
Hammami *et al.*	1.848	0.469	0.220	0.927	2.768	3.935	0.000
Hernandez *et al.* (randomized)	1.848	0.469	0.220	0.927	2.768	3.935	0.000
Hernandez *et al.* (non-randomized)	-0.098	0.690	0.477	-1.451	1.255	-0.142	0.887
Kamalakkannan *et al.* (with weights)	0.611	0.510	0.260	-0.389	1.611	1.197	0.231
Kamalakkannan *et al.* (without weights)	0.254	0.502	0.252	-0.729	1.238	0.507	0.612
Makhlouf *et al.* (balance-jump)	1.277	0.448	0.201	0.399	2.155	2.850	0.004
Makhlouf *et al.* (agility-jump)	0.261	0.420	0.176	-0.562	1.084	0.622	0.534
Poomsalood and Pakulanon	0.757	0.655	0.429	-0.526	2.040	1.156	0.248
Ramirez-Campillo *et al.* (non-optimal)	0.286	0.353	0.124	-0.406	0.977	0.810	0.418
Ramirez-Campillo *et al.* (optimal)	0.678	0.362	0.131	-0.033	1.388	1.870	0.061
Ramirez-Campillo *et al.* (1 session/week)	0.227	0.679	0.461	-1.103	1.558	0.335	0.738
Ramirez-Campillo *et al.* (2 sessions/week)	0.041	0.612	0.375	-1.159	1.242	0.068	0.946
Ramirez-Campillo *et al.* (before soccer)	0.424	0.505	0.255	-0.566	1.413	0.839	0.401
Ramirez-Campillo *et al.* (after soccer)	0.230	0.489	0.239	-0.729	1.189	0.470	0.639
Ramirez-Campillo *et al.* (single surface)	0.697	0.693	0.480	-0.661	2.056	1.006	0.315
Ramirez-Campillo *et al.* (combined surfaces)	0.367	0.617	0.381	-0.842	1.576	0.595	0.552
Sedano *et al.*	3.574	0.721	0.519	2.162	4.986	4.959	0.000
Vaczi *et al.*	0.880	0.428	0.183	0.042	1.718	2.058	0.040
Vlachopoulos *et al.*	0.646	0.375	0.140	-0.088	1.380	1.724	0.085
Yanci *et al.* (2 sessions/week)	0.301	0.485	0.235	-0.650	1.252	0.621	0.535
Yanci *et al.* (1 sessions/week)	1.026	0.528	0.279	-0.010	2.062	1.941	0.052
	0.733	0.144	0.021	0.452	1.015	5.109	0.000

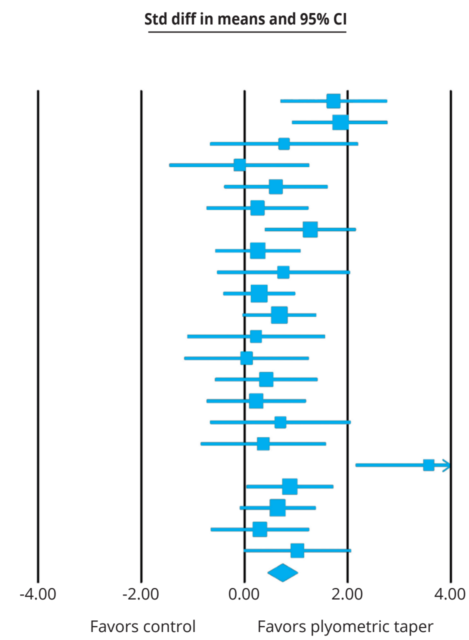

Figure 2.—Forest plot of increases in jump performance after a plyometric jump training with taper compared to controls for the studies included in the meta-analysis.[11, 28, 46-57]
Values shown are effect sizes with 95% confidence intervals (CI).
Std diff: standard difference.

tribution. In the sensitivity analysis to assess the robustness of the summary estimates, with each study deleted from the model once, the results remained consistent (P<0.001).

Risk of bias across studies

The percentage of total variation across the studies due to heterogeneity was low I^2 (18.2%, P=0.22) for the difference in means, and the Egger test yielded a P=0.7.

Additional analysis

Table IV shows a summary of the effects of moderator variables. Regarding the duration of the taper (days), the PJT programs that used a taper <7days or >7 days demonstrated moderate effects (ES=0.80 [95% CI: 0.41-1.19], *Z*=4.0 [P<0.001]; ES=0.71 [95% CI=0.32-1.09], *Z*=3.6 [P<0.001], respectively), with no significant differences between the two strategies (P=0.7).

TABLE IV.—*Effect of moderator variables on jump performance after plyometric jump training with taper.*

Subgroup	Effect size with 95% confidence interval	Effect descriptor	Groups	N.	Within-group I^2 (%)	Within-group P[a]	Between-group P[b]
≤7 days of taper	0.80 (0.41-1.19)	Moderate	7	54	22.5	<0.001	0.744
>7 days of taper	0.71 (0.32-1.09)	Moderate	15	224	50.6	<0.001	
≤40% training volume decrease	1.18 (0.36-1.99)	Moderate	6	64	73.0	0.005	0.196
>40% training volume decrease	0.61 (0.37-0.86)	Moderate	14	214	2.3	<0.001	
<1,011 total jumps[c]	0.67 (0.37-0.97)	Moderate	11	139	4.7	<0.001	0.610
>1,011 total jumps	0.82 (0.33-1.31)	Moderate	11	139	61.2	0.001	

[a]Test of null (2-tail), mixed model; [b]P value, heterogeneity, total between, mixed model; [c]the categorization of total volume was performed according to the median split technique.

Regarding the decrease in training volume (%), the PJT programs that used a taper <40% or >40% demonstrated moderate effects (ES=1.18 [95% CI=0.36-1.99], *Z*=2.8 [P=0.005]; ES=0.61 [95% CI=0.37-0.86], *Z*=4.9 [P<0.001], respectively), with no significant differences between the two tapering approaches (P=0.2). The PJT programs which incorporated a taper after a total volume of <1011 or >1011 jumps demonstrated moderate effects (ES=0.67 [95% CI: 0.37-0.97], *Z*=4.4 [P<0.001]; ES=0.82 [95% CI: 0.33-1.31], *Z*=3.3 [P=0.001], respectively), with no significant differences between the two training volumes (P=0.6).

Discussion

The aim of this systematic review and meta-analysis was to determine the effect of PJT programs applied in conjunction with preplanned tapering strategies on the jump performance of team-sport athletes. In general, from 7020 records identified, 14 studies were eligible for meta-analysis, which resulted in a moderate and significant improvement in jumping ability (ES=0.73; P<0.001). Moreover, similar significant improvements in jump performance were observed after analyzing the duration of the taper (≤7 or >7 days; ES=0.80 and 0.71, respectively) and the number of jumps before the tapering (<1011 and >1011 jumps; ES=0.67 and 0.82, respectively). Lastly, a volume-based taper of PJT load of ≤40% or >40% showed distinct magnitudes of increases in jump capacity (ES=1.18 and 0.61, respectively). The results of this meta-analysis revealed the crucial importance of incorporating a taper regime during PJT in order to maximize performance enhancements in team-sport players.

Increases in jumping height in response to PJT programs have been extensively reported in numerous sport disciplines.[3, 4, 33, 43] These respective improvements in performance may be related to biomechanical (*e.g.* changes in joint knee angle), neuromechanical (*e.g.*, increased motor unit recruitment), or structural (*e.g.* increased muscle fiber pennation angle) factors, among others.[7] Interestingly, the results of the current review indicate that these adaptations are not significantly modified or reduced by the adoption of a tapering period and can be achieved by using different taper strategies and arrangements (*i.e.* total taper volume or duration, and type of PJT load applied before the taper). Notably, the use of tapering schemes following PJT has been associated with decreased levels of fatigue at the end of training interventions,[58, 59] which potentially leads to increased neuromuscular performance.[60, 61]

In fact, the implementation of taper periods seems to be an efficient approach, regularly used by coaches and sports scientists to promote significant performance gains in some periods of the season (*e.g.* close to competitions).[12, 18, 23] Specifically in team-sports, the high volume of matches and technical-tactical workouts typically faced by elite players makes the implementation of taper strategies difficult over the course of competitive seasons.[62, 63] Nevertheless, in the course of training periods lasting between 4 and 8 weeks (*i.e.* preseason phases)[12, 18, 23] or during less congested in-season phases, adequate tapering approaches have been shown to be very effective. Indeed, based on our results, these strategies seem to be equally useful for both shorter (≤7 days) and longer (>7 days) time periods. In this sense, from an applied perspective, athletes' subjective perceptions of wellness (*e.g.* soreness or muscular discomfort) may be simple and good indicators to determine the best phases for implementing efficient tapering strategies.[28] An illustration of this occurrence can be found in the study by Vlachalopolous *et al*.[28] in which a taper was not planned *a priori*, but a progressive reduction in the volume of PJT was applied throughout the final 12 weeks of the intervention due to consistent reports of muscle soreness.

The meta-analytical data obtained here support the use of tapering, especially during some specific preparatory periods in team-sport athletes. Importantly, lower reductions in training volume (≤40%) appear to be the more effective to significantly improve jumping performance. However, decrements in training volume superior to 40% (in relation to total PJT volume) also yielded beneficial outcomes; hence, practitioners and researchers may use both methods in a flexible manner, provided they adopt a non-aggressive strategy for gradually reducing training volume. Unfortunately, none of the studies comprised in the current meta-analysis exhibited follow-up measures over periods where extremely reduced volumes of PJT were executed or no type of plyometric exercise was performed. This information would be important for coaches to understand more clearly about the prospective adaptations of PJT and how these positive responses may be maintained throughout the competitive season.

Limitations of the study

There are some potential limitations to the current meta-analysis. Only 14 studies were available for the use of moderator analyses. As a consequence, the current results should be interpreted with caution and confirmed through future research. Additionally, the dichotomization of continuous data (*e.g.* ≤7 days compared to >7 days) with the median split technique could have resulted in residual confounding and reduced statistical power.[64] Finally, the studies included in this meta-analysis comprised athletes from different sports, training backgrounds, and competitive levels, which can be considered as potential confounding factors. Nonetheless, the inclusion of high-quality studies and the low risk of bias in the assessed manuscripts may be viewed as very positive aspects of this review. In summary, PJT interventions implemented in conjunction with preplanned tapering approaches are able to produce significant improvements in the jump performance of team-sport athletes. These effects can be observed after different taper strategies and seem to be independent of the taper scheme (*i.e.* taper-volume and duration) and the type of PJT applied before this respective phase. Further studies are warranted to confirm these outcomes and compare the possible benefits of training under different tapering protocols.

Conclusions

Tapering strategies are commonly used by coaches and sport scientists to optimize sport performance in top-level athletes. This meta-analysis supports previous findings[2, 12, 23, 43] and confirms that, when progressively applied in conjunction with PJT, a planned taper is effective in improving jumping capacity in team-sport players. Despite some differences among these respective approaches (*e.g.* volume reduction or taper duration) and their potential effects on neuromuscular abilities, practitioners are encouraged to implement adequate tapering phases during plyometric training interventions in order to induce superior increases in sport form and maximize athletic performance. According to the data reported here, the taper schemes can be effectively prescribed and applied in a very flexible manner, over shorter (≤7 days) or longer (>7 days) time periods, and using lower (≤40%) or higher (>40%) rates of volume reduction in PJT volume.

References

1. de Villarreal ES, Kellis E, Kraemer WJ, Izquierdo M. Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. J Strength Cond Res 2009;23:495–506.

2. Sáez de Villarreal E, Requena B, Cronin JB. The effects of plyometric training on sprint performance: a meta-analysis. J Strength Cond Res 2012;26:575–84.

3. Sáez-Sáez de Villarreal E, Requena B, Newton RU. Does plyometric training improve strength performance? A meta-analysis. J Sci Med Sport 2010;13:513–22.

4. Andrade DC, Beltrán AR, Labarca-Valenzuela C, Manzo-Botarelli O, Trujillo E, Otero-Farias P, *et al.* Effects of Plyometric Training on Explosive and Endurance Performance at Sea Level and at High Altitude. Front Physiol 2018;9:1415.

5. Taube W, Leukel C, Gollhofer A. How neurons make us jump: the neural control of stretch-shortening cycle movements. Exerc Sport Sci Rev 2012;40:106–15.

6. Komi PV, Gollhofer A. Stretch reflex can have an important role in force enhancement during SSC-exercise. J Appl Biomech 1997;13:451–9.

7. Markovic G, Mikulic P. Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. Sports Med 2010;40:859–95.

8. Slimani M, Chamari K, Miarka B, Del Vecchio FB, Chéour F. Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. J Hum Kinet 2016;53:231–47.

9. Ramirez-Campillo R, Álvarez C, García-Hermoso A, Ramírez-Vélez R, Gentil P, Asadi A, *et al.* Methodological characteristics and future directions for plyometric jump training research: A scoping review. Sports Med 2018;48:1059–81.

10. Ramírez-Campillo R, Andrade DC, Izquierdo M. Effects of plyometric training volume and training surface on explosive strength. J Strength Cond Res 2013;27:2714–22.

11. Ramirez-Campillo R, Alvarez C, García-Pinillos F, Sanchez-Sanchez J, Yanci J, Castillo D, *et al.* Optimal reactive strength index: is it an accurate variable to optimize plyometric training effects on measures of physical fitness in young soccer players? J Strength Cond Res 2018;32:885–93.

12. Mujika I. Tapering and peaking for optimal performance. Champaign, IL: Human Kinetics; 2009.

13. Hortobágyi T, Houmard JA, Stevenson JR, Fraser DD, Johns RA, Israel RG. The effects of detraining on power athletes. Med Sci Sports Exerc 1993;25:929–35.

14. Izquierdo M, Ibañez J, González-Badillo JJ, Ratamess NA, Kraemer WJ, Häkkinen K, *et al.* Detraining and tapering effects on hormonal responses and strength performance. J Strength Cond Res 2007;21:768–75.

15. Houmard JA. Impact of reduced training on performance in endurance athletes. Sports Med 1991;12:380–93.

16. Vollaard NB, Cooper CE, Shearman JP. Exercise-induced oxidative stress in overload training and tapering. Med Sci Sports Exerc 2006;38:1335–41.

17. Neary JP, Martin TP, Quinney HA. Effects of taper on endurance cycling capacity and single muscle fiber properties. Med Sci Sports Exerc 2003;35:1875–81.

18. Bosquet L, Montpetit J, Arvisais D, Mujika I. Effects of tapering on performance: a meta-analysis. Med Sci Sports Exerc 2007;39:1358–65.

19. Barnes KR, Hopkins WG, McGuigan MR, Northuis ME, Kilding AE. Effects of resistance training on running economy and cross-country performance. Med Sci Sports Exerc 2013;45:2322–31.

20. Cormie P, McGuigan MR, Newton RU. Influence of strength on magnitude and mechanisms of adaptation to power training. Med Sci Sports Exerc 2010;42:1566–81.

21. Kenney WL, Wilmore J, Costill D. Physiology of Sport and Exercise. Champaign, IL: Human Kinetics; 2015.

22. Houmard JA, Johns RA. Effects of taper on swim performance. Practical implications. Sports Med 1994;17:224–32.

23. Mujika I, Padilla S, Pyne D, Busso T. Physiological changes associated with the pre-event taper in athletes. Sports Med 2004;34:891–927.

24. Higgins JP, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, *et al.* Cochrane handbook for systematic reviews of interventions. Chichester: John Wiley & Sons; 2019.

25. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, *et al.* The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 2009;339:b2700.

26. Chu D, Myer G. Plyometrics. Champaign: Human Kinetics; 2013.

27. Moran J, Ramirez-Campillo R, Granacher U. Effects of Jumping Exercise on Muscular Power in Older Adults: A Meta-Analysis. Sports Med 2018;48:2843–57.

28. Vlachopoulos D, Barker AR, Ubago-Guisado E, Williams CA, Gracia-Marco L. The effect of a high-impact jumping intervention on bone mass, bone stiffness and fitness parameters in adolescent athletes. Arch Osteoporos 2018;13:128.

29. Turner HM, Bernard RM. Calculating and synthesizing effect sizes. Contemp Issues Commun Sci Disord 2006;33:42–55.

30. Slinde F, Suber C, Suber L, Edwén CE, Svantesson U. Test-retest reliability of three different countermovement jumping tests. J Strength Cond Res 2008;22:640–4.

31. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. Phys Ther 2003;83:713–21.

32. de Morton NA. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. Aust J Physiother 2009;55:129–33.

33. Stojanović E, Ristić V, McMaster DT, Milanović Z. Effect of Plyometric Training on Vertical Jump Performance in Female Athletes: A Systematic Review and Meta-Analysis. Sports Med 2017;47:975–86.

34. Skrede T, Steene-Johannessen J, Anderssen SA, Resaland GK, Ekelund U. The prospective association between objectively measured sedentary time, moderate-to-vigorous physical activity and cardiometabolic risk factors in youth: a systematic review and meta-analysis. Obes Rev 2019;20:55–74.

35. García-Hermoso A, Ramírez-Campillo R, Izquierdo M. Is Muscular Fitness Associated with Future Health Benefits in Children and Adolescents? A Systematic Review and Meta-Analysis of Longitudinal Studies. Sports Med 2019;49:1079–94.

36. Deeks JJ, Higgins JP, Altman DG. Analysing data and undertaking meta-analyses. In: Higgins JP, Green S, editors. Cochrane Handbook for Systematic Reviews of Interventions: The Cochrane Collaboration. Hoboken, NJ: John Wiley & Sons; 2008. p.243–96.

37. Kontopantelis E, Springate DA, Reeves D. A re-analysis of the Cochrane Library data: the dangers of unobserved heterogeneity in meta-analyses. PLoS One 2013;8:e69930.

38. Hardy RJ, Thompson SG. A likelihood approach to meta-analysis with random effects. Stat Med 1996;15:619–29.

39. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 2009;41:3–13.

40. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ 2003;327:557–60.

41. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med 2002;21:1539–58.

42. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ 1997;315:629–34.

43. Moran J, Clark CC, Ramirez-Campillo R, Davies MJ, Drury B. A meta-analysis of plyometric training in female youth: its efficacy and shortcomings in the literature. J Strength Cond Res 2019;33:1996–2008.

44. Moran J, Sandercock G, Ramirez-Campillo R, Clark CC, Fernandes JF, Drury B. A meta-analysis of resistance training in female youth: its effect on muscular strength, and shortcomings in the literature. Sports Med 2018;48:1661–71.

45. Moran J, Sandercock GR, Ramírez-Campillo R, Meylan C, Collison J, Parry DA. A meta-analysis of maturation-related variation in adolescent boy athletes' adaptations to short-term resistance training. J Sports Sci 2017;35:1041–51.

46. Chtara M, Rouissi M, Haddad M, Chtara H, Chaalali A, Owen A, *et al.* Specific physical trainability in elite young soccer players: efficiency over 6 weeks' in-season training. Biol Sport 2017;34:137–48.

47. Hammami M, Gaamouri N, Shephard RJ, Chelly MS. Effects of Contrast Strength vs. Plyometric Training on Lower-Limb Explosive Performance, Ability to Change Direction and Neuromuscular Adaptation in Soccer Players. J Strength Cond Res 2019;33:2094–103.

48. Hernández S, Ramirez-Campillo R, Álvarez C, Sanchez-Sanchez J, Moran J, Pereira LA, *et al.* Effects of Plyometric Training on Neuromuscular Performance in Youth Basketball Players: A Pilot Study on the Influence of Drill Randomization. J Sports Sci Med 2018;17:372–8.

49. Kamalakkannan K, Azeem K, Arumugam C. The effect of aquatic plyometric training with and without resistance on selected physical fitness variables among volleyball players. J Phys Educ Sport 2011;11:95–100.

50. Makhlouf I, Chaouachi A, Chaouachi M, Ben Othman A, Granacher U, Behm DG. Combination of Agility and Plyometric Training Provides Similar Training Benefits as Combined Balance and Plyometric Training in Young Soccer Players. Front Physiol 2018;9:1611.

51. Poomsalood S, Pakulanon S. Effects of 4-week plyometric training on speed, agility, and leg muscle power in male university basketball players: A pilot study. Kasetsart J 2015;36:598–606.

52. Ramirez-Campillo R, Álvarez C, García-Pinillos F, García-Ramos A, Loturco I, Chaabene H, *et al.* Effects of Combined Surfaces vs. Single-Surface Plyometric Training on Soccer Players' Physical Fitness. J Strength Cond Res 2020;34:2644–53.

53. Ramirez-Campillo R, Alvarez C, Gentil P, Loturco I, Sanchez-Sanchez J, Izquierdo M, *et al.* Sequencing Effects of Plyometric Training Applied Before or After Regular Soccer Training on Measures of Physical Fitness in Young Players. J Strength Cond Res 2020;34:1959–66.

54. Ramirez-Campillo R, García-Pinillos F, García-Ramos A, Yanci J, Gentil P, Chaabene H, *et al.* Effects of Different Plyometric Training Frequencies on Components of Physical Fitness in Amateur Female Soccer Players. Front Physiol 2018;9:934.

55. Sedano Campo S, Vaeyens R, Philippaerts RM, Redondo JC, de Benito AM, Cuadrado G. Effects of lower-limb plyometric training on body composition, explosive strength, and kicking speed in female soccer players. J Strength Cond Res 2009;23:1714–22.

56. Váczi M, Tollár J, Meszler B, Juhász I, Karsai I. Short-term high intensity plyometric training program improves strength, power and agility in male soccer players. J Hum Kinet 2013;36:17–26.

57. Yanci J, Castillo D, Iturricastillo A, Ayarra R, Nakamura FY. Effects of Two Different Volume-Equated Weekly Distributed Short-Term

Plyometric Training Programs on Futsal Players' Physical Performance. J Strength Cond Res 2017;31:1787–94.

58. Pritchard HJ, Barnes MJ, Stewart RJ, Keogh JW, McGuigan MR. Higher- Versus Lower-Intensity Strength-Training Taper: Effects on Neuromuscular Performance. Int J Sports Physiol Perform 2019;14:458–63.

59. Twist C, Highton J. Monitoring fatigue and recovery in rugby league players. Int J Sports Physiol Perform 2013;8:467–74.

60. Becker J, Wu WF. Integrating biomechanical and motor control principles in elite high jumpers: A transdisciplinary approach to enhancing sport performance. J Sport Health Sci 2015;4:341–6.

61. Lorger M, Hraski M, Hraski Z. The effects of motor learning on results of standing long jump performed by female students. Sport Sci (Travnik) 2012;5:27–31.

62. Folgado H, Duarte R, Marques P, Sampaio J. The effects of congested fixtures period on tactical and physical performance in elite football. J Sports Sci 2015;33:1238–47.

63. Palucci Vieira LH, Aquino R, Lago-Peñas C, Munhoz Martins GH, Puggina EF, Barbieri FA. Running Performance in Brazilian Professional Football Players During a Congested Match Schedule. J Strength Cond Res 2018;32:313–25.

64. Altman DG, Royston P. The cost of dichotomising continuous variables. BMJ 2006;332:1080.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions.—Rodrigo Ramirez-Campillo, Lucas A. Pereira, David Andrade, Guillermo Méndez-Rebolledo, Carlos I. de La Fuente, Mauricio Castro-Sepulveda, Felipe Garcia-Pinillos, Tomás T. Freitas and Irineu Loturco have given substantial contributions to manuscript design and protocol research, Rodrigo Ramirez-Campillo and David Andrade to data analysis and interpretation, Rodrigo Ramirez-Campillo, Lucas A. Pereira, Tomás T. Freitas and Irineu Loturco to manuscript writing. All authors read and approved the final version of the manuscript.

History.—Article first published online: July 16, 2020. - Manuscript accepted: July 15, 2020. - Manuscript revised: June 25, 2020. - Manuscript received: April 27, 2020.