

Effects of Plyometric Training on Physical Performance of Young Male Soccer Players: Potential Effects of Different Drop Jump Heights

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1 **Plyometric training in young male soccer players: potential effect of jump height**

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3 *Running head: Transference effect of plyometrics in youth soccer*

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25 **ABSTRACT**

26 **Purpose:** To compare the effects of plyometric drop jump training against those induced by
27 regular soccer training, and to assess the transference effect coefficient (TEC) of drop-jumps
28 (“trained exercises”) performed from 20- [DJ20] and 40-cm [DJ40] height boxes with respect
29 to different physical qualities (jumping; linear and change of direction speed; kicking;
30 endurance; maximal strength) in youth male soccer players. **Methods:** Participants were
31 randomly divided into a control group (n=20; age: 13.5±1.9 years) and a drop jump (DJ)
32 training group (n=19; age: 13.2±1.8 years); and trained for 7 weeks. To calculate the TEC
33 between DJ20-DJ40 and the physical tests, the ratio between the “result gain” (effect-size
34 [ES]) in the analyzed physical qualities and the result gain in the trained exercises were
35 calculated. The TECs were only calculated for variables presenting an $ES \geq 0.2$. **Results:**
36 Significant improvements ($ES=0.21-0.46$; $P < 0.05$) were observed in the DJ training group,
37 except in linear sprint performance. The control group improved only maximal strength
38 ($ES=0.28$). Significant differences were observed in all variables ($ES=0.20-0.55$; $P < 0.05$)
39 in favor of the DJ training group, except for maximal strength. Greater TECs were observed
40 for DJ40 (0.58-1.28) than DJ20 (0.55-1.21). **Conclusion:** Our data suggest that youth players
41 can improve their physical performance through the use of drop jumps. This is the first study
42 that used the TEC to demonstrate the carry-over effect of plyometric training using drop
43 jumps on physical performance of young soccer players.

44

45 **Keywords:** resistance training; neuromuscular training; force-velocity; maturity; football.

46

47

48 **INTRODUCTION**

49 Although aerobic capacity is important during a soccer game (50), high-intensity
50 single-bout efforts also play an important role for physical performance (5, 14). This includes
51 sprinting, jumping, changing direction, and kicking actions (50, 58). Youth elite and sub-
52 elite players were found to be faster, more agile and powerful than non-elite players (17, 54),
53 whereas future international players usually present superior levels of speed and power at
54 youth level than future amateur players (19). Therefore, improvements of such abilities
55 through adequate training strategies may be considered and prioritized from a young age (20,
56 28, 34), potentially leading toward optimal adulthood motor capacity (32).

57 Plyometric jump training (PJT) seems to be an effective way to promote progressive
58 improvements in the neuromuscular abilities, as well as helping in the injury prevention (3,
59 37). These positive effects of PJT includes soccer players of different maturity status and age
60 ranges (3, 4, 33). Interventions with PJT has the advantage of promoting meaningful
61 increases in athletic performance even in congested fixture periods (i.e., in-season) (9, 44).
62 Moreover, PJT may induce a carry-over (i.e., gains in a untrained exercise in relation to a
63 trained PJT exercise) of its specific neuromechanical gains to explosive motor-tasks, such as
64 maximum acceleration actions and maximum short sprints (22, 28).

65 To implement safe and effective PJT programs, several methodological aspects must
66 be considered (38), such as the volume (11, 41) and intensity of the jumps (1, 39), the landing
67 surfaces, order of drills execution, recovery time (41, 47), and the type of training exercises
68 (7, 43), including those that stress the musculotendinous unit (52) (e.g., drop jump [DJ]) (7).
69 DJ is probably the most frequently used and investigated type of PJT drill (38). When
70 properly implemented, either isolated or combined with other drills, DJ has already proved
71 to be practical, safe and very effective to improve physical performance of youth soccer
72 players with different maturity status (30, 31, 38, 40). However, the carry-over effects of the

73 DJ gains to physical performance of young soccer players has not been described yet (21-23,
74 57).

75 The study of the transference effect of DJ training to relevant physical qualities of
76 soccer players may help coaches and researchers to select the most efficient drills, optimize
77 the training load and reduce injury risk (10, 27). To calculate this transference effect, previous
78 recommendations have been provided (60). Zatsiorsky's transference coefficient (60) is a
79 valuable tool for assessing meaningful changes in actual performance (e.g., CMJ, MB5,
80 COD, 5RM, 2400-m TT, MKD) due to a "non-specific training stimulus" (e.g., DJ). To our
81 knowledge, only four studies have analyzed the transference effect coefficient (TEC) of
82 distinct strength and power training strategies on physical performance of athletes and non-
83 athletes (21-23, 57). However, none of the aforementioned studies: i) determined the TEC of
84 a drop jump training scheme; ii) determined the TEC in youth athletes (i.e., athletes with ages
85 ranging from 10 to 16 years); iii) determined the TEC in a test battery that considered jumps,
86 sprint, agility, endurance, strength, and kicking ability.

87 Considering that different PJT drills may induce different effects on the physical
88 fitness of youth male soccer players (42, 43), clarification is needed regarding the TEC
89 induced by drop jumps. In addition, considering that the effects of PJT may vary according
90 to the maturity and age of the participants (13, 31), and the relevance of jumping (2), sprinting
91 (14), change of direction speed (50), endurance (55), kicking and maximal strength (58) in
92 soccer, it was considered relevant to clarify these issues. Thus, the aim of this study was to
93 compare the effects of plyometric drop jump training against those induced by regular soccer
94 training, and to assess the TEC of drop-jumps ("trained exercises") performed from 20-
95 [DJ20] and 40-cm [DJ40] height boxes with respect to different physical capacities (jumping,

96 linear and change of direction speed, kicking, endurance, and maximal strength) of youth
97 male soccer players.

98

99 **METHODS**

100 *Study Design*

101 To compare the effects of plyometric drop jump training against those induced by
102 regular soccer training, and to assess the TEC of DJ20 and DJ40 on jumping, linear and
103 change of direction speed, kicking, endurance and maximal strength in youth male soccer
104 players, athletes were randomly allocated into two groups as follows: DJ training group and
105 control group (CG, soccer players performing a regular soccer training program). The TEC
106 was considered as the gains in an untrained exercise in relation to a trained drop jump
107 exercise. In another words, the TEC was the difference between the improvement in the DJ20
108 and DJ40 and the improvement in the other physical performance tasks in the youth soccer
109 players who trained in drop jumps (see *Statistical Analyses* for a complete description of its
110 calculation).

111 Before and after a 7-week training period, players from both groups executed a series
112 of physical assessments, recorded by the same investigators who were blind to the
113 intervention. Before performing these respective tests, the players executed a 90-minute
114 familiarization session in order to reduce possible learning effects. Measurements were
115 performed over two non-consecutive days, after a 48-h resting period, under similar weather,
116 time, and field conditions. On day 1, players executed: countermovement jump (CMJ), DJ20
117 and DJ40; the 5 alternated leg bounds test (MB5); 20-m sprint test; and Illinois COD test. On
118 day 2, they performed: the maximum kicking distance (MKD) test, and a 2400-m time trial
119 (TT). Players were instructed to arrive at the sports laboratory in a fasted state for at least 2-

120 h. A standardized warm-up was performed before the tests. The warm-up comprised light to
121 moderate self-selected running for 5-min with a 180° change of direction every ~20-m, 10
122 submaximal countermovement jumps, 10 submaximal DJ20, without the incorporation of
123 dynamic stretching exercises. Moreover, sub-maximal attempts at each test were also
124 executed prior to the maximal tests.

125

126 *Participants*

127 Thirty-nine male young soccer players of four different soccer teams with similar
128 competitive and training schedules (1 official game per week and regular soccer training
129 twice a week) took part in this study. The inclusion criteria to participate in this study
130 comprised: 1) more than 2-year background of systematic soccer training and competition
131 experience, 2) continuous soccer training in the previous 6 months, 3) no DJ training
132 experience in the previous 6 months, 4) no background in regular strength training or
133 competitive sports activity that involved any kind of DJ training during the experimental
134 period.

135 Soccer players were randomly divided into two groups: CG [(n = 20; age: 13.5 ± 1.9
136 years; height: 1.55 ± 0.11 m; weight: 49.1 ± 12.0 kg; genital maturation stage 2 (n = 3), stage
137 3 (n = 4), stage 4 (n = 6) and stage 5 (n = 7)] and DJ training group [(n = 19; age: 13.2 ± 1.8
138 years; height: 1.54 ± 0.11 m; weight: 48.6 ± 9.9 kg; genital maturation stage 2 (n = 3), stage
139 3 (n = 3), stage 4 (n = 7) and stage 5 (n = 6)]. The genital maturation was determined by self-
140 assessment of Tanner stage (51) as a measure of the athlete's maturation status.

141 An institutional review board approved the study, and all subjects, their parents or
142 guardians, were informed about the experimental procedures and possible risks and benefits
143 associated with participation in the study. An appropriate parental signed informed consent

144 document and participant assent were obtained pursuant to law before any tests were
145 performed.

146

147 *Training Program*

148 The study was performed during the mid-portion of the competitive (in-season)
149 period. A detailed description of the usual soccer training applied during this period is shown
150 in Table 1. Before the competitive period, participants completed two months of summer
151 preseason training, including body-weight strength and power drills, were drop jumps where
152 introduced with a technical competency approach. Before starting the DJ training period, a
153 session was used, where the participants were re-instructed and reminded in relation to the
154 appropriate execution of the DJ, where screening for technical competency was assessed.
155 During the interventional period, the DJ training group replaced part of the technical training
156 content with drop jumps, within the usual 90-minute practice, twice a week separated by at
157 least 48-h, for 7 weeks. All DJ training sessions lasted ~20 minutes and were performed after
158 the warm-up, on a grass soccer field. From week 1 to week 7, all drop jump training sessions
159 included 3 sets of 10 repetitions of drop jumps from 20- and 40-cm box heights (i.e., 60
160 contacts), with 15 and 90 seconds of rest between repetitions (48) and sets, respectively.
161 Participants were instructed to jump for maximal height and minimum contact time, every
162 jump, to maximize reactive strength (i.e., bounce drop jumps). Despite their maximal effort,
163 athletes were always required to perform the movements with technical efficiency. Therefore,
164 progression was not allowed until adequate competency was acquired. In addition, to limit
165 stress on the muscle-tendon unit, a very conservative number of jumps were used per training
166 session (38, 41). To assure adequate progression and monitoring, a “coach:athlete ratio” of
167 1:4 was used during all drop jump training sessions, that follow previous guidelines (35, 53).

168 For the different soccer teams, the drop jump training was administered by the same coaches.
169 Although the training volume was not increased during the 7-week period, as high-intensity
170 drills (i.e., drop jumps) were performed, this was considered as an adequate training stimulus
171 during each plyometric session (24, 36, 45).

172

173 *****INSERT TABLE 1 HERE*****

174

175 *Vertical Jump Tests*

176 Vertical jump tests comprised CMJ, DJ20, and DJ40. All jumps were performed on a
177 contact mat (Ergojump; Globus, Codogne, Italy) with arms on the hips. Take-off and landing
178 were standardized to full knee and ankle extension on the same spot. The participants were
179 instructed to maximize jump height and minimize ground contact time during the drop jumps.
180 Five attempts were performed for each test. The highest jump for the CMJ and the best
181 reactive strength index (RSI) for the DJs, calculated as jump height (mm) divided by contact
182 time (ms), as previously reported (59), were retained for analysis.

183

184 *Multiple 5 Bounds Test.*

185 The MB5 test was started from a standing position. Players performed a set of 5
186 forward jumps with alternative left- and right-leg contacts, covering the longest distance
187 possible. The distance of the MB5 was measured to the nearest 0.5-cm using a tape measure
188 (29).

189

190 *Five Repetition Maximum Test (5RM)*

191 The test was applied as previously described (41). Briefly, a parallel squat test was
192 performed, where participants had to complete 5 consecutive repetitions with the highest
193 possible load (kilograms).

194

195 *Twenty-Meter Sprint Test*

196 The sprint time was measured to the nearest 0.01 seconds using single beam infrared
197 reds photoelectric cells (Globus Italia, Codogne, Italy). The starting position was
198 standardized to a still split standing position with the toe of the preferred foot forward and
199 behind the starting line. The photoelectric signal was positioned at 20-m and set ~0.7-m
200 above the floor (i.e., hip level) to capture the trunk movement rather than a false trigger from
201 a limb. The soccer players sprinted twice, and the fastest time was retained for the analyses.

202

203 *Illinois Change of Direction Speed Test*

204 The Illinois COD test was performed as previously described (16). Briefly, the test is
205 set up with 4 cones forming the agility area. To perform the test, athletes run 9.2-m, turn, and
206 return to the starting line. After returning to the starting line, they swerve in and out of 4
207 markers, completing two 9.2-m sprints to finish the agility course. The timing system and
208 procedures were the same as the 20-m sprint, except that subjects started lying on their
209 stomach on the floor with their face down. The soccer players performed two attempts, and
210 the fastest time was retained for the analyses.

211

212 *Maximal Kicking Distance Test*

213 Following previous guidelines (46), participants kicked a soccer ball for maximal
214 distance on a soccer field. Participants performed 3 valid attempts for a maximal instep kick

215 with their dominant leg after a run up of two strides. A 75-m metric tape was placed between
216 the kicking line and across the soccer field. The distance was measured to the nearest
217 centimeter. All measurements were completed with a wind velocity $<20\text{-km.h}^{-1}$ (local
218 Meteorological Service). A new size 5 soccer ball (Nike Seitiro, FIFA certified) was used for
219 all measurements.

220

221 *The 2400-m Time Trial Test.*

222 As previously recommended (46), the 2400-m TT test was used because of its
223 multifaceted demands (maximal oxygen consumption, lactate threshold, running economy,
224 muscle power) (12), which are likely to affect soccer performance. After a warm-up run of
225 800-m and four minutes of rest, players individually performed six laps of a 400-m outdoor
226 dirt track, timed to the nearest second, with a stopwatch. The wind velocity and its direction
227 at baseline and post-training was similar (i.e., $7.8\text{-}9.9\text{ km.h}^{-1}$), with a relative humidity
228 between 50 and 70%, and a temperature between 15 and 20° C (local Meteorological
229 Service), respectively. Motivation was considered maximal as the test was conducted as part
230 of the team selection process for the next scheduled match of the in-season.

231

232 *Statistical Analyses*

233 All values are reported as mean \pm standard deviation. Normality was checked using
234 the Shapiro-Wilk test. Analyses of variance were used to test for interactions in between-
235 group comparisons and training-effects over time. Bonferroni post-hoc test was performed
236 to indicate statistically significant differences. The level of significance used was set at $P <$
237 0.05 . All calculations were performed using IBM-SPSS Statistics for Windows, Version 20.0
238 (IBM Corp., Armonk, NY, USA). To determine the magnitude of the differences between

239 the groups pre and post-training and its delta changes, the effect size (ES: Cohen's *d*) was
240 calculated (18). The ES magnitudes were interpreted using the following thresholds: <0.2,
241 0.2-0.6, 0.6-1.2, 1.2-2.0, 2.0-4.0, and >4.0 for trivial, small, moderate, large, very large, and
242 near perfect, respectively (18).

243 The TEC was calculated as previously described, using a within-group analysis,
244 considering its ability to differentiate the transference effects of different exercises performed
245 by a given group of participants (60). Although a within-group analysis was used for the
246 calculation of the TEC, such analysis was employed after the verification of the assumption
247 that the training drills (i.e., DJ20 and DJ40) were effective (induced a meaningful effect), as
248 compared to a control group.

249 The TEC is a theoretical method (60), validated in previous studies (21-23, 57) which
250 demonstrated its ability to differentiate the transference effects of different types of training
251 in different types of athletes; including some forms of plyometric drills (e.g., vertical and
252 horizontal jumps) in soccer players (22). Similar to the ES norms previously described, to
253 evaluate the TEC, a magnitude-based inference approach is applied, using the ratio between
254 the result gain (ES) in the analyzed physical qualities (e.g., CMJ, MB5, COD, 5RM, 2400-m
255 TT, and MKD; also considered as the "non-trained exercises" (60) and the result gain in the
256 trained exercises (e.g., DJ20_{RSI}, DJ40_{RSI}). The TECs were only calculated for variables
257 presenting an ES of at least 0.2, considered a small ES based on Cohen's principle (18).

258

259 **RESULTS**

260 High within-session intraclass correlation coefficients were obtained for CMJ, DJ20,
261 DJ40, MB5, 20-m sprint, COD, and MKD performance tests, varying between 0.81 and 0.98.
262 No significant differences between groups were observed before or after training in the

263 anthropometric measures, age, or maturity status, and no within-group changes were
264 observed ($P > 0.05$). Although 39 soccer players completed the study, 8 players did not, due
265 to lack of comply with inclusion criteria (i.e., completion of all familiarization sessions [n=1],
266 training sessions [n=5], and tests [n=2]). Of note, although some players manifested mild
267 delayed onset of muscle soreness during the first week of drop jump training, no injury
268 associated with the program was observed during the intervention.

269 Table 2 demonstrates the comparison between the DJ training group and CG in the
270 variables tested pre- and post-training period. No significant differences were observed in
271 the physical tests performed, comparing both groups in the pre-measures ($P > 0.05$). When
272 comparing the changes from pre to post training, the DJ training group showed significant
273 small improvements in all variables tested (ES varying from 0.21 to 0.46; $P < 0.05$), with the
274 exception of the 20-m sprint time. In the CG, a significant impairment in the 20-m sprint and
275 COD speed performances were observed (ES = 0.22 and 0.26, respectively; $P < 0.05$), while
276 a significant increase in the 5RM test was observed (ES = 0.28; $P < 0.05$), when comparing
277 pre- and post-assessments. When comparing the groups for changes from pre to post training,
278 significant differences were observed in all variables tested (ES varying from 0.20 to 0.55; P
279 < 0.05), with the exception of the 5RM test for which no significant difference was found (P
280 > 0.05). Figure 1 depicts the TEC between the analyzed physical qualities (CMJ, MB5, COD,
281 5RM, 2400-m TT, and MKD) and the trained exercises (DJ20_{RSI}, DJ40_{RSI}). Sprinting time in
282 20-m did not achieve a significant improvement during the intervention; therefore, the TEC
283 was not calculated. Although the TECs between DJ20 and the physical qualities ranged from
284 0.55 to 1.21 (i.e., CMJ = 0.55; MB5 = 0.71; COD = 0.71; 5RM = 0.87; 2400-m TT = 0.58;
285 MKD = 1.21) on average, greater TECs were observed for DJ40 in relation to the same

286 measure, from 0.58 to 1.28 (i.e., CMJ = 0.58; MB5 = 0.75; COD = 0.75; 5RM = 0.92; 2400-
287 m TT = 0.61; MKD = 1.28).

288

289 *****INSERT TABLE 2 HERE*****

290

291 *****INSERT FIGURE 1 HERE*****

292

293 **DISCUSSION**

294 Our main findings suggest significant improvements (ES = 0.21-0.46; $P < 0.05$) in
295 the DJ training group, except in linear sprint performance. The control group improved only
296 maximal strength (ES = 0.28; $P < 0.05$). Significant differences were observed in all variables
297 (ES=0.20-0.55; $P < 0.05$), in favor of the DJ group, except for maximal strength. In the DJ
298 group, greater TECs were observed for DJ40 (0.58-1.28) than DJ20 (0.55-1.21) (Figure 1).

299

300 Since there was no change in the physical fitness of the CG, and considering the
301 aforementioned characteristics of both training programs, it can be inferred that the
302 improvements observed in the DJ training group were a direct result of the respective DJ
303 drills. Although several researchers have demonstrated that various models of PJT programs
304 were able to increase youth soccer players' performance (6, 38), to our knowledge, this is the
305 first study to assess the TECs of DJ training with respect to different physical traits of youth
306 athletes. Despite its practical relevance, the absence of this calculation in some investigations
307 can be explained by the applied experimental procedures and the impossibility to control and
308 isolate the specific training stimulus (i.e., "trained exercise"). Therefore, comparison of our
309 results with previous studies is difficult due to differences in trained exercises, physical

310 fitness measurements, and characteristics of the participants (i.e., adults). However, a few
311 studies have already applied this calculation. In one study (57) young (mean age, 23.7 years)
312 males and females completed 9 weeks of squat training with different ranges of motion (i.e.,
313 depth vs. shallow). The TEC for deep squats was 2.32 for standing vertical jump and 1.68
314 for depth vertical jump, substantially greater than for shallow squats (0.31 and 0.11,
315 respectively). In a more recent study (23), physically active adult males (mean age, ~20
316 years) obtained greater TECs in different measures of physical fitness after a 9-week training
317 period of traditional strength-power training (TEC = 1.24-3.32) than complex training (TEC
318 = 0.9-2.19). Accordingly, a study conducted with under-20 (mean age, ~18 years) soccer
319 players (22) compared the TECs of a group that trained 3 weeks with either vertical jumps
320 (i.e., CMJ) or horizontal jumps. In the vertically-trained group, the TEC between the vertical
321 jump (i.e., CMJ) and 20-m sprinting speed was 1.31, and for acceleration in 10-20-m was
322 2.75. In the horizontally-trained group, the TEC between the horizontal jump and 10-m
323 sprinting speed was 0.44, for 20-m sprinting speed was 0.17, and for acceleration in 0-10-m
324 was 0.44. Moreover, when under-20 (mean age, ~18 years) male soccer players trained for 6
325 weeks with either jump squat or push-press exercises at the optimum power load (21), a
326 meaningful TEC was detected only for those players that trained with jump squats, obtaining
327 TECs between 0.77-1.29 for 5-, 10-, 20-, and 30-m sprints. Nonetheless, to date, no study
328 has examined the transference effects of drop jumps with respect to a more comprehensive
329 variety of fitness attributes. Researchers may consider to assess the TEC of the trained
330 exercises, by including a test battery with such trained exercises among the dependent
331 variables.

332 The larger TEC observed for DJ40 compared to DJ20 (Figure 1) may be due to the
333 proposed neuromuscular adaptations induced by PJT (24). Nevertheless, the underlying

334 mechanisms leading to potentially greater neuromuscular adaptations after DJ40 compared
335 to DJ20 are not clear, since no physiological measurements were conducted in the current
336 study. The greater TEC with DJ40 (0.58 to 1.28) compared to DJ20 (0.55 to 1.21) may be
337 related to the potentially greater intensity achieved with higher heights (8). Indeed, several
338 PJT studies have reported that to increase the intensity-based load during training, the height
339 of the jump boxes was progressively increased, including studies in youth soccer players (15,
340 38). In this sense, among male volleyball players (mean age, 24.4 years) a 40-cm drop height
341 was demonstrated to induce 22% greater intensity (i.e., reactive strength index) compared to
342 a 20-cm drop height (1). If among highly jump-trained individuals a 40-cm drop height
343 demonstrated greater intensity compared to a 20-cm drop height, this may also be the case
344 for youth soccer players. Therefore, greater height during drop jump drills may have
345 stimulated greater neuromuscular adaptations and, thus, greater TECs. In fact, in the
346 aforementioned study, which compared 20-cm and 40-cm drop jumps, a 31% greater jump
347 height was observed after jumping from a 40-cm height. From a mechanical perspective, the
348 greater jumping height achieved may reflect greater participation of the stretch-shortening
349 cycle governing mechanisms (i.e., stretch reflex; H-reflex) (52), which are especially relevant
350 in youths under growth and maturation (37). In this sense, a larger stretch-shortening cycle
351 may be accompanied by greater muscle activation, including key muscle groups for players
352 such as the medial gastrocnemius, biceps, and rectus femoris (1), thus contributing to the
353 larger TEC observed for DJ40. Moreover, a greater PJT intensity may also be associated to
354 morphological adaptations (24), especially under the influence of growth and maturation
355 (37). However, recently was found that plyometric jump training may induce physical fitness
356 improvements in youth (mean age, ~12 years) male soccer players without changes in muscle
357 activation (26). To clarify this issue, further research should be conducted regarding the

358 identification of potential underlying mechanisms of different types of plyometric jump
359 training drills and it's TEC on different measures of physical fitness among youth male
360 soccer players.

361 Although in our study the DJ40 induced greater TEC than the DJ20, logistical
362 constraints and methodological issues (i.e., young players, 13.2 ± 1.8 years of age) impeded
363 us from incorporating training sessions or even measurements using 60-cm drop jumps.
364 Therefore, we were unable to determine if additional increases in drop heights during DJ
365 training would further improve the TEC. However, in a previous study with youth (15-16
366 years-old) male basketball athletes (25), six weeks of DJ training using either 50- or 100-cm
367 drop jump height boxes resulted in similar improvements between groups in jump height
368 (i.e., 4.8- and 5.6-cm, respectively), muscle strength, and rate of force development.
369 Moreover, whether drop heights equal to or greater than 50-cm are beneficial or even
370 appropriate for youth athletes is still controversial. In fact, drop heights of 50-cm or greater
371 in male youth (mean age, ~13 years) soccer players may exceed optimal training stimulus
372 (39). Although an increase from 20- to 40-cm drop jump height could increase reactive
373 strength index, jump height, and muscle activity, it has been reported that additional increases
374 do not ensure greater training intensities, and may even reduce potential improvements in
375 athletic performance, even among highly jump-trained adult athletes (1). Nevertheless, such
376 assumptions should be confirmed in future studies.

377 A potential limitation of this study is the absence of other treatment conditions (i.e.,
378 another group performing alternative exercises), thereby avoiding comparisons between
379 different neuromuscular training schemes. On the other hand, the possibility of isolating the
380 "trained exercises" (i.e., drop jumps) and determining their transference effects with respect
381 to some important soccer-specific capacities has crucial importance for training

382 interventions. Based on our results, coaches involved in youth soccer should consider
383 implementing plyometric training programs using drop jumps, in substitution for extended
384 technical training practices. This strategy could be very effective in optimizing the physical
385 fitness and kicking performance of youth soccer players, requiring a light volume of jumps
386 (~60 jumps per session), two times per week, and 15-20 minutes per session.

387

388 **CONCLUSION**

389 Compared to a CG, in-season replacement of some low-intensity technical soccer
390 drills with maximal-effort DJ drills induced significant improvements in the athletic
391 performance of male youth soccer players, during a short-term period of 7 weeks. In the DJ
392 group, compared to DJ20 drills, on average, greater TECs (i.e., 0.58-1.28) were observed for
393 DJ40 drills with respect to a wide variety of physical attributes of male youth soccer players.
394 Hence, male youth players were able to improve CMJ, MB5, COD, 5RM, 2400-m TT, and
395 MKD through the use of DJ20 and DJ40, but with a greater TEC being observed for the
396 DJ40. Further studies should be conducted to compare the transference effects of different
397 plyometric drills (e.g., vertical versus horizontal jumps) and other strength-power exercises
398 (e.g., loaded jumps) on physical and technical qualities of youth athletes of different sport
399 disciplines. Considering the lack of studies dealing with the effects of different types of jump
400 drills on youth male soccer player's physical and technical abilities (38) and the TEC between
401 these, current results offer novel findings. Therefore, the present results expand the limited
402 knowledge available regarding the plastic heterogeneity of different physical-technical
403 qualities of youth male soccer players when a short-term in-season program is applied using
404 DJ20 and DJ40 drills.

405 Of practical relevance and as lines of future research, current results would allow the
406 selection of more efficient DJ training drills, potentially reducing the load needed to achieve
407 a given effect, thus reducing the risk of injury associated to greater PJT loads observed in
408 young (mean age, ~19 years) male and female athletes (10), which may also be the case for
409 youth male soccer players. Alternatively, the selection of more efficient drills would allow
410 the addition of complementary key PJT drills or similar conditioning exercises, potentially
411 leading toward greater adaptations, as previously observed in youth male soccer players (42,
412 43).

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607 **FIGURE CAPTION**

608

609 **Figure 1.** Transference effect coefficients for the drop jump trained group between the
610 analyzed physical qualities (i.e., countermovement jump [CMJ]; 5 alternated leg bounds test
611 [MB5]; Illinois change-of-direction test [COD]; 5 repetition maximum test [5RM] in the
612 squat exercise; maximal kicking distance test [MKD]; 2400-m time trial [TT]) and the
613 “trained exercises” (i.e., drop jumps from boxes heights of 20- and 40-cm [DJ20 and DJ40]),
614 after a 7-week training period.

Table 1. Schematic presentation of a typical training session.

Type of training	Duration (min)
Technical (goal shooting, ball control, passing drills)	20
Tactical (defensive and offensive situations, counter-attack, corner kick situations)	20
Small-sided games (different formats with distinct pitch sizes, number of players, and rules modification)	20
Simulated matches	30

Table 2. Comparisons of the physical tests pre- and post- a 7-week training period for both groups of young soccer players.

	Control Group			Drop Jump Training			Group x time interaction
	Pre [#]	Post	ES (\pm 90% CI) <i>Rating</i>	Pre [#]	Post	ES (\pm 90% CI) <i>Rating</i>	ES (\pm 90% CI) <i>Rating</i>
CMJ (cm)	27.1 \pm 4.8	27.3 \pm 4.4	0.05 (\pm 0.09) <i>Trivial</i>	27.2 \pm 5.6	28.4 \pm 5.7*	0.21 (\pm 0.08) <i>Small</i>	0.20 (\pm 0.12)* <i>Small</i>
DJ20 _{RSI} (mm·ms ⁻¹)	1.09 \pm 0.41	1.03 \pm 0.38	0.13 (\pm 0.15) <i>Trivial</i>	1.07 \pm 0.43	1.24 \pm 0.38*	0.38 (\pm 0.12) <i>Small</i>	0.55 (\pm 0.20)* <i>Small</i>
DJ40 _{RSI} (mm·ms ⁻¹)	1.09 \pm 0.35	1.05 \pm 0.32	0.11 (\pm 0.18) <i>Trivial</i>	1.05 \pm 0.44	1.22 \pm 0.49*	0.36 (\pm 0.10) <i>Small</i>	0.50 (\pm 0.19)* <i>Small</i>
MB5 (m)	8.85 \pm 1.17	8.87 \pm 1.14	0.02 (\pm 0.03) <i>Trivial</i>	9.12 \pm 1.16	9.44 \pm 1.23*	0.27 (\pm 0.12) <i>Small</i>	0.25 (\pm 0.12)* <i>Small</i>
Time 20-m (s)	4.33 \pm 0.52	4.45 \pm 0.38*	0.22 (\pm 0.19) <i>Small</i>	4.25 \pm 0.53	4.21 \pm 0.54	0.07 (\pm 0.07) <i>Trivial</i>	0.31 (\pm 0.21)* <i>Small</i>
COD speed (s)	19.6 \pm 0.28	20.3 \pm 2.9*	0.26 (\pm 0.07) <i>Small</i>	20.1 \pm 2.8	19.4 \pm 2.4*	0.27 (\pm 0.09) <i>Small</i>	0.55 (\pm 0.12)* <i>Small</i>
2400-m TT (min)	10.6 \pm 0.9	10.6 \pm 0.9	0.03 (\pm 0.10) <i>Trivial</i>	10.5 \pm 0.8	10.3 \pm 0.7*	0.22 (\pm 0.11) <i>Small</i>	0.20 (\pm 0.15)* <i>Small</i>
MKD (m)	32.1 \pm 7.6	31.5 \pm 8.5	0.08 (\pm 0.08) <i>Trivial</i>	33.6 \pm 8.7	37.8 \pm 9.7*	0.46 (\pm 0.14) <i>Small</i>	0.54 (\pm 0.16)* <i>Small</i>
5RM (kg)	31.7 \pm 9.3	33.4 \pm 9.7*	0.19 (\pm 0.16) <i>Small</i>	32.7 \pm 11.1	36.6 \pm 12.1*	0.33 (\pm 0.10) <i>Small</i>	0.11 (\pm 0.18) <i>Trivial</i>

Note: ES: effect sizes; CI: confidence intervals; CMJ: countermovement jump; DJ: drop jump; RSI: reactive strength index; MB5: multiple 5 bounds test; COD: change of direction; TT: time-trial; MKD: maximal kicking distance; RM: repetition maximum. [#]no significant differences were observed at Pre, between groups. * $P < 0.05$.