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Comparative effects of single vs. double weekly plyometric training sessions on jump, sprint and COD abilities of elite youth football players

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Dear reviewer, thanks for your comments and for the time that you have dedicated to this paper. My group an I have really appreciated your indications.

General comment (originality, scientific accuracy, strengths and/or weaknesses): The study is very interesting and useful, providing practical and valuable information for coaches and researchers. In general, it was well written, and presents a god design. However, there are some important aspects that should be improved before final acceptance.
Major corrections (main criticisms): Specific comments

Page 3, line 64: “It seems reasonable to investigate the effects of plyometric training programs of different volume considering that, at elite level, a very limited time can be
dedicated to specific physical development, especially throughout the season, due to the
congested matches fixture (e.g. national and international tournaments) and associated travels.” Authors are correct with such statement, and it is reasonable to study different volumes of plyometric training in soccer players. However, authors should provide more consistent and detailed information about soccer specific training content (i.e., type of training, volume, intensity), and physical fitness training (apart from the plyometrics) during the interventional period. This information is fundamental to help readers to better interpret/understand the results of the study.

Thanks for your indication. Authors added a table that reports a traditional training routine during a week

In addition, there is a great difference in terms of training volume between young soccer players (U18) and adult soccer players. Authors stated that congested fixtures could interfere in the plyometric training adaptations, probably due to the concurrent (interference) training effects. It could be better explored to present the rationale of the study. Please, see and consider the reference (s) below:

Loturco, I., Pereira, L. A., Kobal, R., Zanetti, V., Kitamura, K., Abad, C. C. C., & Nakamura, F. Y. (2015). Transference effect of vertical and horizontal plyometrics on sprint performance of high-level U-20 soccer players. Journal of sports sciences, 33(20), 2182-2191.

Loturco, I., Pereira, L. A., Kobal, R., Zanetti, V., Gil, S., Kitamura, K., ... & Nakamura, F. Y. (2015). Half-squat or jump squat training under optimum power load conditions to counteract power and speed decrements in Brazilian elite soccer players during the preseason. Journal of Sports Sciences, 33(12), 1283-1292.

Thanks. We have improved the quality of the introduction using these papers.

Page 5, line 30: The players trained only 4 times per week and played once a week (every Saturday). From a general perspective, this means that they had 2 rest days per week. Therefore, this training volume is lower than those reported in previous investigations performed with professional soccer players. Do the authors think that this low training volume was responsible to the improvements observed in the LPG performance? Perhaps with a more qualified group of players, training more days per week (resulting in higher training volume, which is the reality of professional soccer teams even in younger categories) just one plyometric training session per week could not have been sufficient/adequate to elicit such adaptations. Authors should present more details about the training content and discuss this question accordingly.

Thanks. Done

Tests

Authors should provide more information about the testing procedures. Mainly for jump and COD tests. Even that they are very popular in professional sport settings, there are many different protocols for these tests, and specific/mode detailed characteristics of each tests should be provided.

Done.

Statistical analysis

It is not clear why did the authors used a 90% confidence interval.

What was the significance level adopted?

Please, insert the effect sizes in the appropriate section od the manuscript.

Thanks. Done.

Data were presented as mean ± standard deviation (SD). Outcomes were expressed as value, with 90% confidence interval (CI). Robust estimates of 90% CI and heteroskedasticity were calculated using bootstrapping technique (randomly 1000 bootstrap samples) .24

Results

Page 6, line 67: it is “table 1”.

Part of the table 1 is missing, then it is not possible to fully interpret/understand the results of the study.

Figure caption should be placed below the figure.

Thanks for your comments. Every indication has been accepted. ES are reported in table 2.

Minor corrections (page, paragraph, line where the author must make the corrections): Discussion

In general, the discussion is well structured and organized. The authors should extend the questions related to the "transference effects" of plyometric training to specific soccer performance, including short-accelerations, and jump & COD tasks (page 8 – line 34). This is conceivably the most important benefit of plyometric exercises for soccer players' performance. (Please, see the reference above by Loturco et al.)

Page 8, line 21: It is difficult to understand why authors think that only the "gender" is a limitation of the study. Wider generalization of the findings cannot be extended even for soccer players with higher volumes of training and matches (e.g., senior soccer players). Authors should revise and extend this specific part of the manuscript.

Conclusions

In my opinion, the authors should not use the findings of this study to recommend training strategies for senior soccer players. I can guarantee that senior soccer players who compete "at the top-level" are not able to improve their speed-power capacities performing only one plyometric training session per week. Certainly, this population depends on greater training frequencies to improve their neuromuscular performance.

Thanks for your comments. Every indication has been accepted.

Introduction

In football, the requirement for frequent changes in the type of movements (e.g., walking, running, sprinting, jumping, tackling), speed (e.g., accelerations, decelerations), direction, and technical tasks features the activity profile as intermittent in nature [1–3]. Briefly, high-intensity running and sprint-type activities are considered to be crucial determinants for successful performance [4]. Previous analyses showed that outfield football players cover distances of between 10 and 13 km during the matches [3]. Of these, 8% to 12% were represented by high-intensity running or sprinting, with inter-player differences occurring due to the specific playing role [3]. Based on the multifaceted nature of physical requirements in football, several methods have been developed to improve players' fitness parameters such as endurance, strength, power and speed [5,6].

During a football match, muscle power and strength are critical physical factors for successful participation [2,7]. Plyometric activities are widely implemented as training methodology for enhancing functional sports performance [8]. Plyometric training generally involves bounding exercises (e.g. multiple jumps), as well as high-impact exercises (e.g. drop jumps) [9–11]. Previous studies found that a combination of vertical and horizontal plyometric exercises offer practical advantages compared with methods that involve a single directional component (e.g. only vertical or horizontal jumps) [6,12]. These conditioning activities, eliciting improvements of the mechanical muscle properties (i.e. strength, power and rate of force development) that cover a great functional role for most of the demanded movements of a football match, which may have a critical impact of the match physical performances such as sprinting, change of directions (COD), side cutting, throwing and fights situations [4,10,13–15].

The literature suggests that the plyometric training effects may depend on several key variables, including: the volume, the frequency, and the duration of the protocol, as well as the period of the season and the subjects' fitness characteristics [16–18]. Training variables management has a critical impact on players' fitness adaptations that occur in elite youth football players [19]. However, despite the popularity and wide appeal of plyometric training, few published studies have employed a randomised trial design involving elite young players. Although several studies have analysed the plyometric training-induced effects with a frequency of 2-3 times a week (effect size (ES) from 0.26 to 2.8), few of them provided evidences supporting an equal efficiency of similar training programs implementing lower training frequency such as one training session a week [10]. It seems reasonable to investigate the effects of plyometric training programs of different volume considering that, at elite youth level, a very limited time can be dedicated to specific physical development due to the congested matches fixture (e.g. national and international tournaments) and associated travels [20].

To date, evidences about the effect of a single plyometric session a week are limited, and few are the randomised trial involving elite young players [21,22]. Moreover, no data are available regarding comparisons between the magnitude of the effects of a single plyometric session a week compared with a higher training volume (twice a week). Therefore, the aim of this study was to compare the effects of two 8-week plyometric training programs including either a single or two sessions a week, on the on jump, sprint and COD abilities of young elite football players during the pre-season period.

Methods

Participants

Twenty-three youth football players (elite academy, Switzerland) were considered during the enrolment process. Only outfield players were included (two goalkeepers were excluded). Therefore, twenty-one participants were included in the current study (mean ± SD; age 17 ± 0.8 years, weight 70.1 ± 6.4 kg, height 177.4 ± 6.2 cm). All participants were informed about the potential risks and benefits of the study and signed an informed consent (parental consent has been given). The Ethics Committee of the Department of Science and Technology, University of Suffolk (UK) approved this study. All procedures were conducted according to the Declaration of Helsinki for human studies.

Design

This study used a randomised pre-post parallel group trial design. The randomisation was performed according to a computer-generated sequence. The participants were then assigned to either a low-volume plyometric training group (LPG = 10 participants) or a high-volume plyometric training group (HPG = 11 participants). Nineteen participants completed the study, while two participants (one for each group) dropped out due to contact injuries not associated with the protocol execution. Every player was considered for the final statistical analysis (intentional to treat analysis). CONSORT participant flow is reported in figure 1 [23]. Considering the players' level, the period of the season, the proximity to international tournaments, and the necessity of elite players to maximise their performance, the investigators took the decision to randomised the sample in two training groups without any control group. The duration of this study was 8 weeks. Training protocols, as well as the baseline tests and post-training assessments, were performed before the beginning of the official season (from August 2017). Players were familiarised with the testing procedures because it was part of the fitness test routine of the club. During this study, the team performed 4 training session a week as team practices as well as an official match every Saturday (Friday and Sunday were days off).

Tests

The participants replicated the same tests 3 times, with an adequate recovery among the trials and the best scores in every test were used for the data analysis. A long jump test was utilised to evaluate the ability in horizontal non-rebounding jumping task. A single-leg triple hop distance test (triple hop test) was performed with both the legs to evaluate the performance in rebounding jump ability [24]. Players performed 3 consecutive maximal hops forward with the same limb. Arm swing was allowed. The intraclass correlation coefficient (ICC) of this test was 0.95. Sprint 10, 30 and 40 m were performed to evaluate players' improvements in sprint ability. For this purpose, infrared timing gates (Microgate, Bolzano, Italy) were placed at the start and each of the mentioned distances. 505 COD test was utilised to evaluate improvements in the COD ability [25]. On the "Go" command, the subjects were instructed to sprint for 15 m (through the timing gates at 10 m), turn on their preferred foot, and sprint back through the timing gates. The validity and specifically of this test was proved previously in football [25].

Training

LPG performed once time per week (on Monday) a protocol of 4 x 5 drop jumps from 60 cm height followed by a subsequent jump over two obstacles (15 cm height), 4 x 6 horizontal jumps, as well as 4 x 6 jumps over obstacles of 15 cm height. The HJG performed the same protocol but twice a week (Monday and Wednesday). Both groups after the plyometric protocol performed a COD and sprint training (3 sets of 3 short shuttle runs with 4 COD each, for an amount of 36 COD).

Please, table 1 here.

Statistical analysis

In the current study, an intention-to-treat analysis was performed, which involved all the participants as originally randomized and used the baseline values for the follow up (thus, drop out were included in the final analysis, see figure 1) [26]. Data were presented as mean ± standard deviation (SD). Outcomes were expressed as value, with 90% confidence interval (CI). Robust estimates of 90% CI and heteroskedasticity were calculated using bootstrapping technique (randomly 1000 bootstrap samples) [27]. Analysis of variance (ANOVA) was used to evaluate within-group differences. Analysis of covariance (ANCOVA), using baseline values as covariate, was employed to detect possible between-groups differences [28]. When significant F-values were found, post hoc analysis was performed (Bonferroni). The significance level was set at $p \leq 0.05$. ES based on the Cohen d principle was interpreted as trivial <0.2, small 0.2-

0.6, moderate 0.6-1.2, large 1.2-2.0, very large >2.0 [28]. Statistical analyses were performed by SPSS software version 20 for Windows 7, Chicago, USA.

Results

Exercise-induced meaningful changes in performance for both LPG and HPG occurred after the training. Within-group changes for LPG and HPG are reported in Tables 1. However, between-group analysis did not report any statistical difference: long jump (F = 1.118, p = 0.304), triple hop test right (F = 1.576, p = 0.225), triple hop test left (F = 0.388, p = 0.541), 10 m sprint (F = 0.666, p = 0.425), 30 m sprint (F = 0.627, p = 0.439), 40 m sprint (F = 3.50, p = 0.078) and 505 agility (F = 0.706, p = 0.412).

Please, table 2 here.

Discussion

As hypothesised, after 8 weeks of training, meaningful within-group differences were found, with positive effects for both groups (LPG and HPG) in most of the assessed tests (except for the LPG in the 505-COD test). This study shows that both short-term (8 weeks) plyometric protocols offered some meaningful improvements in jump, speed and agility capabilities. However, after the between group analysis, no meaningful differences were found when comparing the effectiveness of the two training protocols.

Plyometric training is a widespread form of physical conditioning that involves jumping exercises wherein the stretch-shortening cycle muscle action represents the potentiating underlying neurophysiological mechanism [1]. Studies generally report that plyometric training regimen is effective for improving neuromuscular impulse-dependent components [10,29,30], with positive transfer effects on specific tasks such as acceleration, jumping, sprinting, and COD ability [12,29,30]. In a recent review, Asadi and colleagues reported positive effects (ES from 0.26 to 2.8) of plyometric training in sports, thus supporting the results found in this study [22]. Moreover, Loturco et al., found that plyometrics can transfer specific neuromuscular gains to acceleration and speed abilities of football players, such findings confirm our results [6]. The data reported in the current study support the positive effect found in previous research studies using plyometric training.

The outcomes found in the current study are particularly interesting since pertaining to elite academy athletes. Elite players are accustomed to performing specific sport related actions, thus, improvements in their fitness capabilities are much harder to achieve when compared with other populations (e.g. amateurs) [31]. This could explain the meaningful but generally small effect found in this study (table 2). The players enrolled in this study have a training frequency of 4 times per week and played once a week (every Saturday). This training volume is lower than that reported in previous investigations performed with professional football players, therefore the positive effects found in this study could be likely smaller whether a senior professional sample (accustomed to higher training volume) would have been involved [10]. Therefore, once plyometric training session per week could not have been sufficient to elicit such adaptations in a different sample (e.g. senior professional players).

As reported above, both LPG and HPG showed improvements in the post-training tests. Nevertheless, we have not found any significant between-group difference following the protocols. However, HPG had a beneficial effect on 505 COD test ($p = 0.039$), while LPG did not report meaningful results ($p = 0.197$). Therefore, this study highlight that a higher plyometric training volume could not be advantageous than a lower one with elite academy players in pre-season (also if it is plausible from a theoretical point of view) [30]. These results could be explained considering the low plyometric volume adopted (around 90 jumps a session), as well as the level of the players enrolled [10,13]. The decision to develop such a plyometric volume per training session was chosen to satisfy the professional duties (based on the competitive calendar) of the players/team, and should not be considered a limitation (it is an ecological protocol).

This study presents some limitations, firstly, the small sample enrolled. A greater sample could have offered a better understanding about the effect obtained by LPG and HPG. Future studies could replicate this protocol to confirm our findings. Another limitation that should be considered is that the adopted research design, including a homogeneous group of youth football players and the lack of an additional parallel control group, may limit the opportunity to make broader generalizations to other populations represented by different age groups or athletes of different levels or gender. Therefore, wider generalisation cannot be inferred and the results could not be extended to other specific populations (e.g. professional male and elite female players).

Conclusions

This study supports previous findings suggesting that one plyometric training session a week may provide a sufficient training-dose leading to meaningful improvements in jump and speed parameters in elite young football players [12,29]. Both LPG and HPG are effective training modalities inducing benefits in jump tests, as well as in 10, 30 and 40 m sprint tests for elite young football players. Fitness coaches and sports scientists could integrate their training plans with the protocols described in this study. Due to the lack of statistical difference between LJG and HJG, authors recommend using a low plyometric training volume equivalent to 80-100 jumps a week during the pre-season for improving jump, sprinting and COD abilities in elite young football players. Future studies are needed to confirm the results of this study.

Comparative effects of single vs. double weekly plyometric training sessions on jump, sprint and COD abilities of elite youth football players

Mattia Bianchi[1], Giuseppe Coratella[2], Antonio Dello Iacono[3,4], Marco Beato[5]

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3. The Academic College at Wingate, Wingate Institute, Netanya, Israel.
4. Sport Science Department, Maccabi Tel Aviv FC, Tel Aviv, Israel.
5. School of Science, Technology and Engineering, University of Suffolk, Ipswich, UK.

Abstract

BACKGROUND: Plyometrics are widely implemented as training methodology for enhancing functional sports performance. Although several studies have analysed the plyometrics effects due to training plans with a frequency of 2-3 times a week, few of them provided evidence supporting an equal efficiency of similar training programs implementing lower training frequency such as one training session a week.

METHODS: Twenty-one players (elite academy, Switzerland) were included in the current study (mean ± SD; age 17 ± 0.8 years, weight 70.1 ± 6.4 kg, height 177.4 ± 6.2 cm). This study used a randomised pre-post parallel group trial design**.** The participants were assigned to either a low-volume plyometric training group (LPG = 10 participants) or a high-volume plyometric training group (HPG = 11 participants). A long jump test, a single-leg triple hop test, sprint (10, 30 and 40 m) and 505 change of directions (COD) test were performed.

RESULTS: Exercise-induced meaningful changes in performance for both LPG and HPG occurred after the training. LPG and HPG reported improvements in long jump (ES=1.0 and

0.77), triple hop right (ES=0.32 and 0.28), triple hop left (ES=0.46 and 0.32), 10 m sprint (ES=0.62 and 1.0). CONCLUSIONS: both LPG and HPG are effective training modalities inducing benefits in jump and sprint tests for elite young football players. Fitness coaches and sports scientists could integrate their training plans with the protocols described in this study.

Keywords: soccer, agility, exercise training

Introduction

In football, the requirement for frequent changes in the type of movements (e.g., walking, running, sprinting, jumping, tackling), speed (e.g., accelerations, decelerations), direction, and technical tasks features the activity profile as intermittent in nature [1–3]. Briefly, high-intensity running and sprint-type activities are considered to be crucial determinants for successful performance [4]. Previous analyses showed that outfield football players cover distances of between 10 and 13 km during the matches [3]. Of these, 8% to 12% were represented by high-intensity running or sprinting, with inter-player differences occurring due to the specific playing role [3]. Based on the multifaceted nature of physical requirements in football, several methods have been developed to improve players' fitness parameters such as endurance, strength, power and speed [5,6].

During a football match, muscle power and strength are critical physical factors for successful participation [2,7]. Plyometric activities are widely implemented as training methodology for enhancing functional sports performance [8]. Plyometric training generally involves bounding exercises (e.g. multiple jumps), as well as high-impact exercises (e.g. drop jumps) [9–11]. Previous studies found that a combination of vertical and horizontal plyometric exercises offer practical advantages compared with methods that involve a single directional component (e.g. only vertical or horizontal jumps) [6,12]. These conditioning activities, eliciting improvements of the mechanical muscle properties (i.e. strength, power and rate of force development) that cover a great functional role for most of the demanded movements of a football match, which may have a critical impact of the match physical performances such as sprinting, change of directions (COD), side cutting, throwing and fights situations [4,10,13–15].

The literature suggests that the plyometric training effects may depend on several key variables, including: the volume, the frequency, and the duration of the protocol, as well as the period of the season and the subjects' fitness characteristics [16–18]. Training variables management has a critical impact on players' fitness adaptations that occur in elite youth football players [19]. However, despite the popularity and wide appeal of plyometric training, few published studies have employed a randomised trial design involving elite young players. Although several studies have analysed the plyometric training-induced effects with a frequency of 2-3 times a week (effect size (ES) from 0.26 to 2.8), few of them provided evidences supporting an equal efficiency of similar training programs implementing lower training frequency such as one training session a week [10]. It seems reasonable to investigate the effects of plyometric training programs of different volume considering that, at elite youth level, a very limited time can be dedicated to specific physical development due to the congested matches fixture (e.g. national and international tournaments) and associated travels [20].

To date, evidences about the effect of a single plyometric session a week are limited, and few are the randomised trial involving elite young players [21,22]. Moreover, no data are available regarding comparisons between the magnitude of the effects of a single plyometric session a week compared with a higher training volume (twice a week). Therefore, the aim of this study was to compare the effects of two 8-week plyometric training programs including either a single or two sessions a week, on the on jump, sprint and COD abilities of young elite football players during the pre-season period.

Methods

Participants

Twenty-three youth football players (elite academy, Switzerland) were considered during the enrolment process. Only outfield players were included (two goalkeepers were excluded). Therefore, twenty-one participants were included in the current study (mean ± SD; age 17 ± 0.8 years, weight 70.1 ± 6.4 kg, height 177.4 ± 6.2 cm). All participants were informed about the potential risks and benefits of the study and signed an informed consent (parental consent has been given). The Ethics Committee of the Department of Science and Technology, University of Suffolk (UK) approved this study. All procedures were conducted according to the Declaration of Helsinki for human studies.

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This study used a randomised pre-post parallel group trial design. The randomisation was performed according to a computer-generated sequence. The participants were then assigned to either a low-volume plyometric training group (LPG = 10 participants) or a high-volume plyometric training group (HPG = 11 participants). Nineteen participants completed the study, while two participants (one for each group) dropped out due to contact injuries not associated with the protocol execution. Every player was considered for the final statistical analysis (intentional to treat analysis). CONSORT participant flow is reported in figure 1 [23]. Considering the players' level, the period of the season, the proximity to international tournaments, and the necessity of elite players to maximise their performance, the investigators took the decision to randomised the sample in two training groups without any control group. The duration of this study was 8 weeks. Training protocols, as well as the baseline tests and post-training assessments, were performed before the beginning of the official season (from August 2017). Players were familiarised with the testing procedures because it was part of the fitness test routine of the club. During this study, the team performed 4 training session a week as team practices as well as an official match every Saturday (Friday and Sunday were days off).

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Training

LPG performed once time per week (on Monday) a protocol of 4 x 5 drop jumps from 60 cm height followed by a subsequent jump over two obstacles (15 cm height), 4 x 6 horizontal jumps, as well as 4 x 6 jumps over obstacles of 15 cm height. The HJG performed the same protocol but twice a week (Monday and Wednesday). Both groups after the plyometric protocol performed a COD and sprint training (3 sets of 3 short shuttle runs with 4 COD each, for an amount of 36 COD).

Please, table 1 here.

Statistical analysis

In the current study, an intention-to-treat analysis was performed, which involved all the participants as originally randomized and used the baseline values for the follow up (thus, drop out were included in the final analysis, see figure 1) [26]. Data were presented as mean ± standard deviation (SD). Outcomes were expressed as value, with 90% confidence interval (CI). Robust estimates of 90% CI and heteroskedasticity were calculated using bootstrapping technique (randomly 1000 bootstrap samples) [27]. Analysis of variance (ANOVA) was used to evaluate within-group differences. Analysis of covariance (ANCOVA), using baseline values as covariate, was employed to detect possible between-groups differences [28]. When significant F-values were found, post hoc analysis was performed (Bonferroni). The significance level was set at $p \leq 0.05$. ES based on the Cohen d principle was interpreted as trivial <0.2, small 0.2-0.6, moderate 0.6-1.2, large 1.2-2.0, very large >2.0 [28]. Statistical analyses were performed by SPSS software version 20 for Windows 7, Chicago, USA.

Results

Exercise-induced meaningful changes in performance for both LPG and HPG occurred after the training. Within-group changes for LPG and HPG are reported in Tables 2. However, between-group analysis did not report any statistical difference: long jump ($F = 1.118$, $p = 0.304$), triple hop test right ($F = 1.576$, $p = 0.225$), triple hop test left ($F = 0.388$, $p = 0.541$), 10 m sprint ($F = 0.666$, $p = 0.425$), 30 m sprint ($F = 0.627$, $p = 0.439$), 40 m sprint ($F = 3.50$, $p = 0.078$) and 505 agility ($F = 0.706$, $p = 0.412$).

Please, table 2 here.

Discussion

As hypothesised, after 8 weeks of training, meaningful within-group differences were found, with positive effects for both groups (LPG and HPG) in most of the assessed tests (except for the LPG in the 505-COD test). This study shows that both short-term (8 weeks) plyometric protocols offered some meaningful improvements in jump, speed and agility capabilities. However, after the between group analysis, no meaningful differences were found when comparing the effectiveness of the two training protocols.

Plyometric training is a widespread form of physical conditioning that involves jumping exercises wherein the stretch-shortening cycle muscle action represents the potentiating underlying neurophysiological mechanism [1]. Studies generally report that plyometric training regimen is effective for improving neuromuscular impulse-dependent components [10,29,30], with positive transfer effects on specific tasks such as acceleration, jumping, sprinting, and COD ability [12,29,30]. In a recent review, Asadi and colleagues reported positive effects (ES from 0.26 to 2.8) of plyometric training in sports, thus supporting the results found in this study [22]. Moreover, Loturco et al., found that plyometrics can transfer specific neuromuscular gains to acceleration and speed abilities of football players, such findings confirm our results [6]. The data reported in the current study support the positive effect found in previous research studies using plyometric training.

The outcomes found in the current study are particularly interesting since pertaining to elite academy athletes. Elite players are accustomed to performing specific sport related actions, thus, improvements in their fitness capabilities are much harder to achieve when compared with other populations (e.g. amateurs) [31]. This could explain the meaningful but generally small effect found in this study (table 2). The players enrolled in this study have a training frequency of 4 times per week and played once a week (every Saturday). This training volume is lower than that reported in previous investigations performed with professional football players, therefore the positive effects found in this study could be likely smaller whether a senior professional sample (accustomed to higher training volume) would have been involved [10]. Therefore, once plyometric training session per week could not have been sufficient to elicit such adaptations in a different sample (e.g. senior professional players).

As reported above, both LPG and HPG showed improvements in the post-training tests. Nevertheless, we have not found any significant between-group difference following the protocols. However, HPG had a beneficial effect on 505 COD test ($p = 0.039$), while LPG did not report meaningful results ($p = 0.197$). Therefore, this study highlight that a higher plyometric training volume could not be advantageous than a lower one with elite academy players in pre-season (also if it is plausible from a theoretical point of view) [30]. These results could be explained considering the low plyometric volume adopted (around 90 jumps a session), as well as the level of the players enrolled [10,13]. The decision to develop such a plyometric volume per training session was chosen to satisfy the professional duties (based on the competitive calendar) of the players/team, and should not be considered a limitation (it is an ecological protocol).

This study presents some limitations, firstly, the small sample enrolled. A greater sample could have offered a better understanding about the effect obtained by LPG and HPG. Future studies could replicate this protocol to confirm our findings. Another limitation that should be considered is that the adopted research design, including a homogeneous group of youth football players and the lack of an additional parallel control group, may limit the opportunity to make broader generalizations to other populations represented by different age groups or athletes of different levels or gender. Therefore, wider generalisation cannot be inferred and the results could not be extended to other specific populations (e.g. professional male and elite female players).

Conclusions

This study supports previous findings suggesting that one plyometric training session a week may provide a sufficient training-dose leading to meaningful improvements in jump and speed parameters in elite young football players [12,29]. Both LPG and HPG are effective training modalities inducing benefits in jump tests, as well as in 10, 30 and 40 m sprint tests for elite young football players. Fitness coaches and sports scientists could integrate their training plans with the protocols described in this study. Due to the lack of statistical difference between LJG and HJG, authors recommend using a low plyometric training volume equivalent to 80-100 jumps a week during the pre-season for improving jump, sprinting and COD abilities in elite young football players. Future studies are needed to confirm the results of this study.

Acknowledgements

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Table 1. A standard weekly programme for an elite youth football team.

Day	Training Programme
Monday	Warm-up, 20 min; **Pliometrics (LPG and HPG) 20 min**; Technical/tactical, 25 min; Play, 15 min
Tuesday	Morning: Strength training and injury prevention (gym), 40 min. Afternoon: Warm-up, 15 min; Technical/tactical, 25 min; Play, 25 min; Moderate-intensity aerobic training or SSG, 20 min
Wednesday	Warm-up, 15 min; **Pliometrics (HPG) 20 min** Technical/tactical, 30 min; Play, 20 min
Thursday	Warm-up, 15 min; Speed training (long and short), 15 min Technical/tactical, 25 min; Play, 15 min
Friday	Day off
Saturday	Match
Sunday	Day off

CODs = Change of directions; SSG = Small sided games

Table 2. Summary of baseline and post-training data before and after 8 weeks of plyometric training, LPG (n = 10) and HPG (n = 11). Data are presented in mean ± SDs.

Variable	Baseline Mean ± SD	Follow-up Mean ± SD	Delta difference (90% CI)	P level	ES (interpretation)
LPG					
Long jump (cm)	2.33 ± 0.15	2.48 ± 0.21	0.15 (0.07; 0.27)	0.030	1.0 (moderate)
Triple hop right (m)	7.02 ± 0.72	7.25 ± 0.56	0.23 (0.12; 0.34)	0.022	0.32 (small)
Triple hop left (m)	6.90 ± 0.60	7.18 ± 0.66	0.28 (0.07; 0.48)	0.031	0.46 (small)
Sprint 10 m (s)	1.84 ± 0.08	1.79 ± 0.08	-0.04 (-0.02; -0.07)	0.003	0.62 (moderate)
Sprint 30 m (s)	4.25 ± 0.15	4.19 ± 0.15	-0.05 (-0.02; -0.09)	0.014	0.4 (small)
Sprint 40 m (s)	5.48 ± 0.24	5.27 ± 0.27	-0.21 (-0.05; -0.04)	0.029	0.87 (moderate)
505 COD test (s)	4.78 ± 0.12	4.69 ± 0.17	-0.08 (0.03; -0.19)	0.197	0.75 (moderate)
HPG					
Long jump (cm)	2.18 ± 0.14	2.30 ± 0.17	0.12 (0.04; 0.20)	0.040	0.77 (moderate)
Triple hop right (m)	6.81 ± 0.52	6.96 ± 0.59	0.15 (0.05; 0.30)	0.021	0.28 (small)

Triple hop left (m)	6.75 ± 0.70	6.96 ± 0.68	0.2 (0.08; 0.33)	0.015	0.32 (small)
Sprint 10 m (s)	1.85 ± 0.07	1.77 ± 0.08	-0.07 (-0.02; -0.12)	0.004	1.0 (moderate)
Sprint 30 m (s)	4.36 ± 0.16	4.26 ± 0.15	-0.09 (-0.04; -0.14)	0.007	0.64 (moderate)
Sprint 40 m (s)	5.52 ± 0.18	5.46 ± 0.17	-0.06 (-0.03; -0.09)	0.004	0.39 (moderate)
505 COD test (s)	4.83 ± 0.16	4.73 ± 0.16	-0.10 (-0.14; -0.01)	0.039	0.64 (moderate)

SD = Standard deviations; CI = Confidence intervals; ES = Effect size, m = meters; s = seconds, COD = Changes of direction, LPG = low volume plyometric group, HPG = high volume plyometric group

Figure 1. CONSORT diagram showing the flow of participants through each stage of a randomized trial.