



*Original Research*

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## **Effect of an 8-Week Plyometric Training Program with Raised Forefoot Platforms on Agility and Vertical Jump Performance**

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### ABSTRACT

*International Journal of Exercise Science 12(6): 491-504, 2019.* Some athletes use solid rubber platforms strapped onto the forefoot during plyometric exercises in order to increase their explosive performance including vertical jump height and agility. The purpose of this study was to compare the effects of a plyometric training program realized with these 'raised forefoot platforms,' designed to keep the heels off the ground, to the same program conducted with regular shoes. Forty-nine subjects performed 2 sessions of plyometric training for eight weeks, either with raised forefoot platforms (n=20) or regular shoes (n=29). Countermovement jump (CMJ) height and agility test time were evaluated at pre-, mid- and post-training program. Compared to baseline values, four and eight weeks of plyometric training significantly increased CMJ and agility performances in the raised forefoot platforms and regular shoes groups. However, compared to regular shoes, wearing raised forefoot platforms during training induced significantly better performances in CMJ at week 4 (+4.4cm) and week 8 (+7.2cm) and in agility at week 8 (-0.466s). Thus, while an 8-week plyometric training program was effective at improving both CMJ and agility performance for both shoe conditions, the improvements were greater for the group wearing raised forefoot platforms.

**KEY WORDS:** Training footwear, stretch-shortening cycle, explosive strength training, muscle power, plantarflexor muscles, injury

### INTRODUCTION

In many sports, athletes must be able to jump high and respond as quickly as possible to a stimulus. Therefore, coaches and athletes are continuously exploring ways to improve muscle power and agility. Muscle power is the amount of work a muscle can produce per unit of time whilst agility is defined as "a rapid whole-body movement with change of velocity or direction in response to a stimulus" (37). Plyometrics is a very popular training method that includes bounding, hopping and depth jumping which seem to be effective for increasing muscle power and vertical jump height (1). Moreover, plyometric exercises involve starting and changing directions in an explosive way, which seems to be recommended to increase agility

performances (37). Furthermore, it has been shown that plyometric training of 6 to 10 weeks contributes to increased vertical jump height (2,4,11,21,24,27,31,42) and agility (24,29,34,40).

Since the 1990s, manufacturers have designed specialized training footwear (Figure 1) to overload the ankle plantarflexor muscles and Achilles tendon to a greater extent than with regular shoes (RS). Manufacturers claim superior effects on vertical jump and sprint performance of this training footwear compared to RS when associated to plyometric training. However, scientific investigations showed that plyometric training for eight to ten weeks with a modified athletic shoe with a 4-cm thick rubber platform attached to the front of the sole (Figure 1A) does not increase vertical jump, sprint and strength performance compared to RS (6,30), with the exception of a significant increase in calf girth (30). Furthermore, a high rate of injury with this type of training footwear was observed (6,30). Better results on vertical jump height and sprint speed were observed when a curvature was placed in the middle of the sole of the shoe (Figure 1B) to help the linear up and down phases of movement during sprints and jumps (20). However, a later study did not show such convincing results in vertical jump and sprint time with the addition of this curvature (32). Manufacturers also designed solid rubber platforms that strap onto the forefoot over the regular shoes (Figure 1C). The aim of these raised forefoot platforms (RFP) is to induce a permanent posterior stretching of the plantarflexors and Achilles tendon during plyometric exercises due to the fact that heels are kept off the ground and the muscle-tendon complex is always under tension. The RFP manufacturers even claim that use of RFPs during plyometric training will result in superior lower-body explosiveness, such as an increased vertical jump height of 12.7 to 25.4 cm and a decreased 40-yard dash time by 0.2 s (18).



**Figure 1.** Pictures of training footwear designed to keep the heels off the ground during exercises: (A) modified athletic shoe with a 4-cm thick rubber platform attached to the front of the sole (Strength Shoe™), (B) modified athletic shoe with a curvature placed in the middle of the sole (Meridian Elyte Shoe™) and (C) solid rubber platforms that strap onto the forefoot over the regular shoes by two dorsal foot straps and one posterior ankle strap (Jumpssoles™).

To our knowledge, no scientific study has focused on RFP efficacy yet. So, the purpose of this study is to investigate the effect of an 8-week plyometric training program performed with RFPs compared to the same program conducted with RS on lower-body muscle power and agility. It is well established that lower-body muscle power can be indirectly assessed through vertical jump performance (15,26). A countermovement jump (CMJ) test is one of the common ways to perform vertical jump test (25). We thus measured the effect of RFP through a CMJ test and an

agility test before, during and after the training period. Compared to RS, we hypothesized that the use of RFP during a plyometric training could induce greater improvements in CMJ and agility.

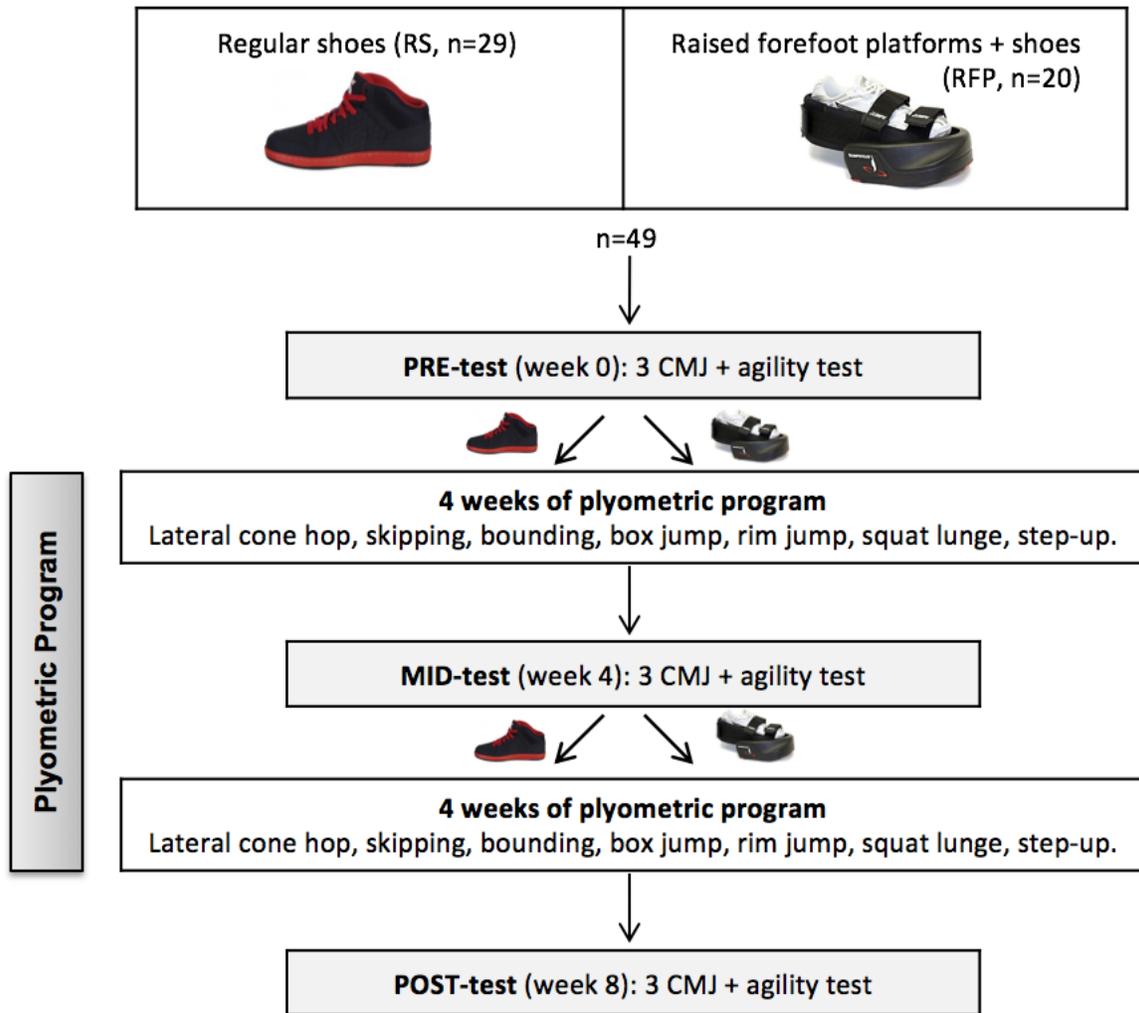
## METHODS

### *Participants*

Fifty-six recreational male basketball players volunteered for this study and were randomly divided into two groups: one wearing RFP (RFP group) and one wearing RS (RS group) during the training sessions. Each subject was fully informed about the risks and benefits of the study and self-reported his ability to practice two plyometric training sessions a week. All subjects signed an informed consent form approved by the Haute Ecole Louvain en Hainaut's Institutional Review Board (Belgium). Parental consent was also obtained for the subjects under the age of 18 years old. They also certified that they did not suffer from recent injuries or invalidating chronic pathologies (respiratory and orthopedic). Subjects of this study played basketball for at least three years. They were used to jump training but only three of them in each group had already followed a plyometric training program. During the study, subjects continued to follow their usual basketball activities, with 1 - 2 training sessions (technical drills and game tactics) and one game per week. They did not practice any other extra activity or muscle-strengthening exercise program.

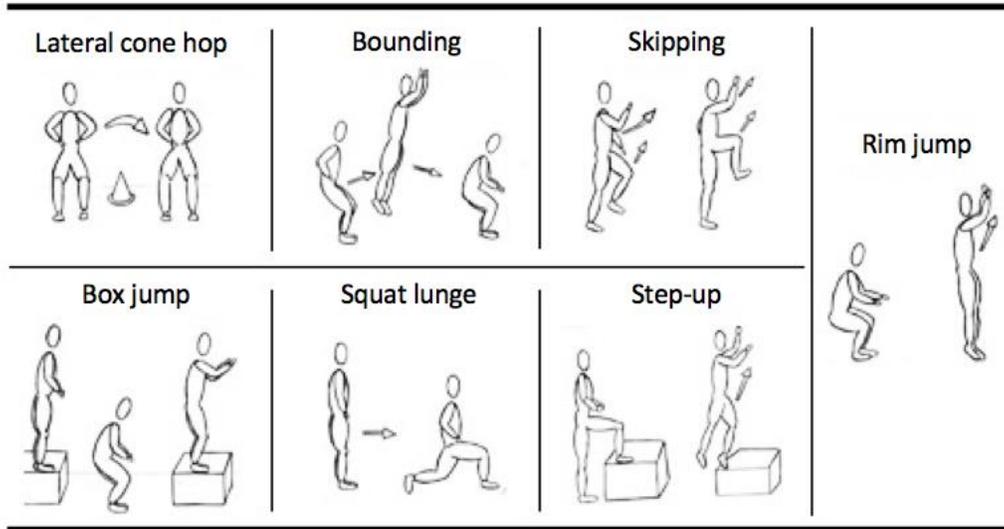
### *Protocol*

All participants followed the same 8-week plyometric training program but during the training sessions, they either wore raised forefoot platforms (Jumpsoles™ v4.0, Metapro - Jump, USA) attached to their own regular shoes (RFP group) or their own regular shoes only (RS group). For the purpose of this study, RS was defined as any type of non-platform training shoe. For each group, testing sessions were conducted at three specific times: PRE- (week 0), MID- (week 4) and POST-training program (week 8) (Figure 2). Agility and CMJ performances were evaluated during each testing session.



**Figure 2.** Experimental design. The exercises of the plyometric program are described in the section *Plyometric training program*. CMJ = countermovement jump.

Plyometric training program: The same plyometric training program, developed by the manufacturers (28), was prescribed for all subjects for eight weeks including two identical sessions per week with at least 48 hours of rest between sessions. The plyometric training program included 30 cm lateral cone hops, 2-legged bounding, skipping, box jumps completed from a height of 40 cm, squat lunges, steps-up from a height of 40 cm and rim jumps (Figure 3). Subjects were instructed to perform all plyometric exercises with maximal effort and to minimize ground contact time. The number of exercises and/or repetitions in the training sessions progressively increased week after week, ranging from a 10-minute low-intensity to a 45-minute moderate-intensity session (Table 1). Each training session started with a 10-minute warm-up consisting of a 500-meter run of low intensity, dynamic mobility exercises and jumping up and down for two minutes. All the subjects wore their own footwear during the warm-up. Thereafter RFP were attached over the regular shoes, by two dorsal foot straps and one posterior ankle strap for the RFP group subjects.



**Figure 3.** Illustration of each exercise included in the plyometric training program. **Lateral cone hop:** Lateral jumping as high as possible above the cones (height: 0.3 m) by keeping the legs straight and the feet ready for the landing before jumping again as quickly as possible. **Bounding:** Spread the legs open as broad as the shoulders and carry out fast and successive jumps by keeping the same space between the feet. **Skipping:** Jump as high as possible on each leg while raising the knee. **Box jump:** Four 0.4-m boxes were placed in parallel and spaced 1.50-m apart. Subjects started on the first box and performed three maximal rebounds, as quickly and high as possible, after dropping from the box. They had to touch the ground with the balls of the feet only. **Squat lunge:** With aligned feet, descend the posterior leg towards the floor keeping the knee of the anterior leg right in the vertical axis of the toes. **Step-up:** Climb a stair step (height 0.4 m) in an explosive way. **Rim jump:** Jumping with straight legs and straight arms successively.

**Table 1.** Plyometric training program (28).

	Week 1	Week 2	Week 3	Week 4	Weeks 5-7	Week 8	Rest (min)
Lateral cone hop	-	1 x 10	1 x 10	2 x 10	2 x 10	2 x 10	2
23 m bounding	-	-	1 x 1	1 x 1	2 x 1	2 x 1	2
23 m skipping	-	1 x 1	1 x 1	2 x 1	2 x 1	3 x 1	1
Box jump	-	-	1 x 10	1 x 10	2 x 10	2 x 10	4
Squat lunge	2 x 10	2 x 10	2 x 10	3 x 10	3 x 10	3 x 10	1
Step-up	2 x 10	2 x 10	2 x 10	3 x 10	3 x 10	3 x 10	1
Rim jump	-	1 x 10	2 x 10	2 x 10	2 x 10	2 x 10	4

Number of sets x number of repetitions is presented for each session of week 1 – 8. Rest is the rest interval between sets. The exercises are illustrated in Figure 3.

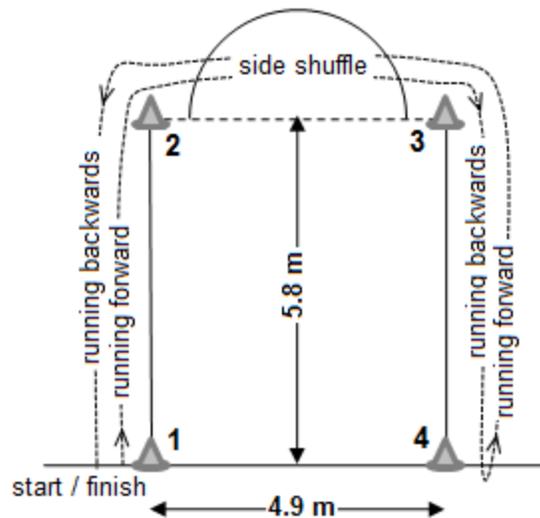
Procedures: As described previously, subjects attended three testing sessions (Figure 2). Anthropometric measures and baseline values for agility and CMJ performances were collected at week 0 before the first session (PRE). Agility and CMJ performances were also collected 72

hours after the second session of week 4 (MID) and finally 72 hours after the last session of the training program (POST). Each testing session included a 5-min warm-up, three CMJ tests, as well as one test of agility. Subjects carried out the testing sessions wearing their own basketball shoes only. Subjects were required to wear the same basketball shoes during each measurement session.

For the CMJ, subjects began in an upright standing position, flexed the knees and jumped immediately upwards. They were instructed to jump as high as possible with their legs straight during the flight time, to land in an upright position and to bend their knees on landing. Because the arm swing increases the CMJ height (15,22) and in order to assess more specifically the lower limb power, they had to keep their hands on the hips during the CMJ. A 5-second rest was observed between each jump and the highest jump was used for subsequent analyses. The CMJ performance was assessed using a portable device Optojump® System (Microgate, Bolzano, Italy) sampling at 1000 Hz. The Optojump® is an optical measurement system which is composed of a transmitting and a receiving bar containing photocells positioned two millimeters from the ground. The photocells from the transmitting bar communicate continuously with those on the receiving bar. The system detects any interruptions in communication between the bars and calculates their duration. Thus, it measures contact and flight times during a jump and calculates jump height (expressed in centimeters) from flight time. The use of Optojump® photoelectric cells is valid and has a high reliability for field-based assessments of CMJ height (13).

The agility test was used to evaluate rapid changes of speed and direction. For this test, four cones were positioned as illustrated in Figure 4. Subjects started with their dominant foot on the start line and proceeded to a series of various displacements from cones 1 to 4 and inversely: running forward (from 1 to 2), right side shuffle (from 2 to 3), running backwards (from 3 to 4), running forward (from 4 to 3), left side shuffle (from 3 to 2) and running backward (from 2 to 1). The agility test was timed to the nearest 1/100th of a second, using a digital stopwatch, from the first movement until the subject crossed the finish line at cone 1. The time was always recorded by the same experimenter. Subjects performed the test twice while only the second trial was timed.

Independently of the three testing sessions of the main experiment, test-retest reliability over a five-day interval between two testing sessions was assessed through the calculation of intraclass correlation coefficient (ICC) for CMJ height and agility test time. Eight subjects (age:  $20.4 \pm 2.9$  years; height:  $178.6 \pm 6.5$  cm; body mass:  $74.1 \pm 13.2$  kg) performed these two sessions at the same time of day to minimize the effect of circadian rhythms.



**Figure 4.** Diagram of the agility test area. The agility test used is adapted from the Lane Agility Test.

### Statistical Analysis

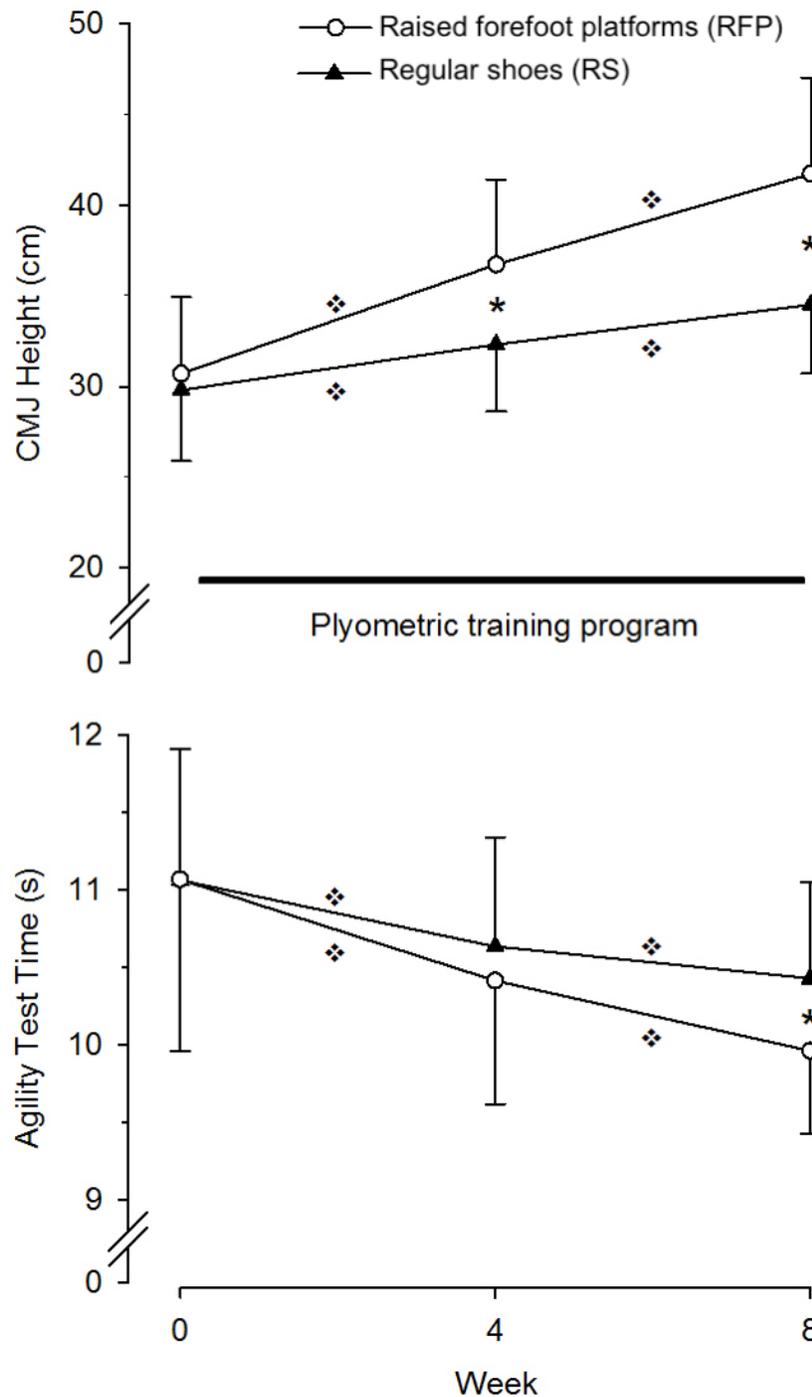
All the analyses were performed by using SigmaPlot (Systat Software, San Jose, CA). Descriptive statistics were calculated for age, weight and height. The assessed experimental variables included the CMJ height and the agility test time. Data were then compared using a two-way (group by testing session) repeated measures ANOVA and the Holm-Sidak method was used to test all pairwise multiple comparisons. An alpha level of 0.05 was set for all statistical tests. Effect sizes for the observed differences between PRE- and POST-test were calculated using Cohen's  $d$  and were interpreted as small ( $d$  between 0.2 and 0.5), moderate ( $d$  between 0.5 and 0.8) or large ( $d > 0.8$ ) (5). The ICCs were calculated using a two-way mixed effects model for single measurement and absolute agreement. CMJ height and agility demonstrated a high test-retest correlation: CMJ height showed a high reliability (ICC = 0.988) whilst agility test time reported a good reliability (ICC = 0.734).

## RESULTS

Seven subjects from the RFP group were unable to complete the prescribed training program and subsequently dropped from the study: three were injured during the 8-week period of the training program (ankle strain, finger fracture and relapse of a shin splint) and four stopped the program for time conflict or lack of motivation. The remaining 49 participants, aged 16 to 30 years old, completed the study: 20 in the RFP group (mean  $\pm$  SD; age:  $20.7 \pm 3.8$  years; height:  $180.9 \pm 7.2$  cm; body mass:  $76.3 \pm 12.2$  kg) and 29 in the RS group (age:  $19.9 \pm 4.4$  years; height:  $182.4 \pm 8.3$  cm; body mass:  $77.9 \pm 12.4$  kg).

The analysis of the CMJ height demonstrated a significant main effect for group ( $p < 0.001$ ) and testing session ( $p < 0.001$ ). The interaction was also significant ( $p < 0.001$ ). The *post-hoc* analysis showed that the CMJ height was similar between the RFP and RS groups at PRE-test ( $30.7 \pm 4.2$  vs  $29.8 \pm 3.9$  cm respectively,  $p = 0.424$ ). The CMJ height also increased after four and further eight

weeks of plyometric training in each group ( $p < 0.001$ ). However, the RFP group showed a significantly higher CMJ at week 4 ( $36.7 \pm 4.7$  vs  $32.3 \pm 3.7$  cm,  $p < 0.001$ ) and at week 8 ( $41.7 \pm 5.3$  vs  $34.5 \pm 3.8$  cm,  $p < 0.001$ ) compared to the RS group (Figure 5 - top).



**Figure 5.** Countermovement jump height (top) and agility test time (bottom) for subjects trained with raised forefoot platforms (○) or regular shoes (▲) at PRE-test (week 0), MID-test (week 4) and POST-test (week 8) of the plyometric

training program. The error bars represent the standard deviation. \* = significantly different between RFP and RS groups. ❖ = significantly different between week 0 and week 4 and between week 4 and week 8.

For agility test time (Figure 5 - bottom), there was a significant main effect for testing session ( $p < 0.001$ ), no main effect for group ( $p = 0.278$ ), and a significant interaction ( $p = 0.014$ ). The *post-hoc* analysis showed that the agility performance was similar between RFP and RS at PRE- and MID-test ( $11.07 \pm 1.10$  vs  $11.06 \pm 0.84$  and  $10.41 \pm 0.80$  vs  $10.63 \pm 0.70$  s respectively,  $p = 0.983$  and  $0.333$ ) and significantly faster for the RFP group at week 8 ( $9.96 \pm 0.53$  vs  $10.43 \pm 0.62$  s,  $p = 0.043$ ). In RFP and RS groups, the time to complete the agility test decreased after four ( $p < 0.001$  and  $p < 0.001$ ) and further eight weeks of plyometric training ( $p < 0.001$  and  $p = 0.043$ ).

All observed differences between PRE- and POST-test showed a large effect size with a Cohen's *d* equal to, respectively for RFP group and RS group, 2.30 and 1.22 for CMJ height and 1.29 and 0.85 for agility test time.

## DISCUSSION

The participants to this study performed a plyometric training program of moderate intensity two days per week for eight weeks. The results have shown that training with raised forefoot platforms resulted in significant improvements in both countermovement jump and agility performances. These improvements were higher than those obtained when plyometric training with regular training shoes.

Several studies have previously reported the effectiveness of a plyometric training of six to ten weeks in improving CMJ performance (4,9,24,27,31,38,39). Plyometrics refers to the performance of stretch-shortening cycle (SSC) movements, i.e. exercises with a brief stretch of the muscle-tendon complex followed immediately by a rapid and powerful shortening contraction of the same muscle. According to the classification of Schmidtbleicher (36), the plyometric program used in our study consists of slow (ground contact time  $> 0.25$  s, for example squat lunge) and fast SSC (ground contact time  $< 0.25$  s, for example box jump). CMJ being an example of slow SSC, the enhancement of performance observed in this jump could be related to the repetition of SSC movements in the training program, which could modify, for example, the mechanical properties of the muscle-tendon complex of plantarflexors (21,10), the muscle or fiber size (4,24,31) and maximal shortening velocity (24) and the motor units' recruitment pattern (41). Thus, changes in neuromuscular function could be responsible for the increased CMJ height in the RS group and in the RFP group.

As shown in the results section, the RFP group showed a larger increase in CMJ height than the RS group. With raised forefoot platforms, the heels are kept off the ground and the center of pressure is shifted to the forefoot, creating an ankle dorsiflexion moment. This could lead to adaptations in different ways. First, a greater overload is placed on the muscle-tendon complex of the plantarflexors, which are always under tension. In quiet standing, Frank et al. (12) observed that these modifications were compensated by an increased activity of the triceps

surae, predominantly eccentric. The higher loads developed during the eccentric contractions with RFP could have resulted in a greater increase in lower-body muscle strength (33) and stiffness (17). An increased stiffness was previously associated with a better vertical jump performance (11). Second, the ankle is predominantly in a dorsiflexed position with RFP. Consequently, potential energy could be stored in larger quantities in the series elastic components through a modified visco-elastic composition of the triceps surae muscle (12). Because the series elastic components account for 70-75 percent of the concentric force increases of muscle (1), it could explain why the players from the RFP group jumped higher. Finally, the plyometric exercises conducted with the RFP group could have modified more significantly the excitability of the proprioceptors, inducing a better reactivity of the neuromuscular system (7,14). In short, we can hypothesize that more specific chronic neuromuscular adaptations after a plyometric program with RFP, potentiating the eccentric phase of the SSC, induced a higher CMJ height.

However, literature shows contradictory results about the effectiveness of two models of shoes also designed to keep the heels off the ground during plyometric training (6,20,30,32). Compared to plyometric training with RS, Cook et al. (6) and Porcari et al. (30) showed no superior effect in vertical jump height when plyometric training with Strength Shoe. Many subjects felt that the overall quality of the Strength Shoe was poor with an inadequate arch support, cushioning and heel cup (30), which could have reduced the training efficiency. In contrast, Kraemer et al. (20) observed better results in vertical jump height with Meridian Elyte Shoe compared to RS after an 8-week plyometric training program of lower intensity than the one used with Strength Shoe. Interestingly, subjects gave a high score for comfortableness to Meridian Elyte Shoe (20). A trend toward a greater rate of force development of the triceps surae muscle at the dorsiflexed ankle position, observed in the subjects of the Meridian Elyte Shoe group, could partially explain the positive effect on vertical jump height (20).

It is worth noting that a gain of 2.5 and 6.0 cm was already observed after four weeks for the RS and RFP groups. To our knowledge, this study is the first to show an increased CMJ height after only four weeks of plyometric training. Previously, Herrero et al. (16) showed no increase and Luebbers et al. (23) even a decrease in CMJ height after a plyometric program of, respectively, two and three sessions a week for four weeks. The higher volume of plyometric training (minimum 165-180 jumps per week) and a smaller recovery period before the testing sessions (48 hours in Luebbers et al. (23) and not stated in Herrero et al. (16)) could have induced an increased fatigue at the time of the testing sessions in these previous studies. Indeed, Luebbers et al. (23) have shown an increased CMJ performance four weeks post-training which seems to confirm the influence of the fatigue. In our study, the players had a low baseline performance for CMJ, in comparison to, for example, male physical education students (27); the duration and the intensity of the training sessions progressively increased from a 10-minute low-intensity in week 1 to a 40-minute moderate-intensity in week 4; and a rest of 72 hours was observed between the last training session and the testing session. Under these conditions, a 4-week plyometric training was sufficient to increase vertical jump performance in recreational male basketball players with a low CMJ baseline.

Our results also showed that subjects from the RS and RFP groups decreased the execution time for the agility test, by respectively 5.7 and 10.0%, after the eight weeks of the plyometric training. These results support agility improvements observed in previous studies through use of other agility tests (shuttle run, T-test, Illinois agility test, 505 agility test), after a plyometric training (24,29,38,40). The plyometric program allows a better reactivity (34,20) and agility could be influenced more by reactive strength than by lower-body muscle power (43). The jumps included in our plyometric program were achieved in an explosive way and implied a relatively short contact time. Moreover, because the muscle-tendon complex of the plantarflexors is always under tension in the RFP group, and as previously discussed, this could induce a better reactivity of the neuromuscular system (7). These characteristics could have positively influenced the agility performance which could be preferentially attributed to neural adaptation. More specifically, the intermuscular coordination could be improved (40). Previous studies on the effects of modified athletic shoes did not evaluate agility (6,20,30,32).

If it is likely that RFP enhance the performance of SSC muscle function through an increased tension in the muscle-tendon complex of the plantarflexors, an excessive overload in that region could induce a higher rate of injury around the ankle. In the present study, two subjects of the RFP group have been injured in the lower leg: one experienced an ankle strain and the other a relapse of a shin splint. With RFP, the ankle stability is more challenged. When the heel is always off the ground in quiet standing, the tibialis anterior activity is strongly increased, which most likely contributes to enhance this ankle stability (12). This increased activity could induce a high level of fatigue in the tibialis anterior and thus contribute to shin splints. Nevertheless, the incidence of injuries observed in our study was similar (20,32) or lower (6,30) than in previous studies on the effect of a plyometric training with a near-similar technical aid. The higher incidence reported with Strength Shoe could be due to a shoe quality described as poor by subjects and a higher intensity of the plyometric training program (6,30). The following characteristics of the plyometric training performed in our study could have reduced the risk of injury: 1) proper warm-up and cool down were realized as recommended by the manufacturers, 2) the number of exercises and/or repetitions was progressively increased week after week, 3) a rest of at least 48 hours was scheduled between two plyometric sessions and 4) a moderate plyometric training frequency (two days per week) was used. Previous studies have indeed shown that, for players with a low-moderate baseline performance, it was not necessary to increase the plyometric training frequency (3,8) or intensity (35).

**Conclusion:** The present investigation has shown that four and eight weeks of plyometric training resulted in significant improvements in both countermovement jump and agility performances in recreational male basketball players. These improvements were higher when plyometric training with RFPs than with RS. However, given the higher risk of injury observed with RFPs, we would recommend using RFPs cautiously in a well-planned plyometric training program preferentially in pre-season. The intensity and duration of the training sessions should be progressively increased, and a proper warm-up and cool-down should be included in each session.

## **DISCLOSURE STATEMENT**

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