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# Enhancing Agility in Basketball: The Impact of an Individualized Drop Jump-Based Post-Activation Performance Enhancement Protocol

## Basketbolda Çevikliğin Geliştirilmesi: Bireyselleştirilmiş Drop Jump Temelli Aktivasyon Sonrası Performans Güçlendirme Protokolünün Etkisi

Research Article / Araştırma Makalesi

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## Abstract

The aim of this research is to examine the acute effect of a jump-based post-activation performance enhancement (PAPE) protocol individualized according to reactive strength index (RSI) values on agility performance in male basketball players. In this experimental study, 20 male basketball players (age=22.1±2.1 years; height=190.9±8.7 cm; body mass= 87.7±9.8 kg) voluntarily participated. In the PAPE protocol applied to the participants, the optimal drop jump (DJ) height was defined as the platform height at which the highest value was obtained during the RSI measurement, and each athlete performed the DJ at this height. A pre-test/post-test design was employed across separate visits. Baseline agility performance was assessed during an earlier session using the Lane Agility Test (LAT), while post-test agility measurements were recorded immediately after the DJ-based PAPE intervention during the final visit. For statistical analysis, a paired-samples t-test was used, and the significance level was set at $p<0.05$. The findings indicate a statistically significant 1.9% improvement in agility time following PAPE ($p=0.039$; ES=0.288). The study underscores the on-court applicability of individualized PAPE approaches and offers concrete recommendations for acute performance gains prior to training.

Keywords: Post-activation performance enhancement, Jump, Reactive strength index, Agility

## Öz

Bu araştırmanın amacı reaktif kuvvet indeksi (RSI) değerlerine göre bireyselleştirilmiş sıçrama temelli aktivasyon sonrası performans güçlendirme (PAPE) protokolünün, erkek basketbolcularda çeviklik performansına olan akut etkisini incelemektir. Bu deneysel çalışmada, 20 erkek basketbolcu (yaş=22.1±2.1 yıl; boy=190.9±8.7 cm; vücut kütlesi=87.7±9.8 kg) gönüllü olarak yer almıştır. Katılımcılara uygulanan PAPE protokolünde, optimal drop jump (DJ) yüksekliği, RSI ölçümünde en yüksek değerin elde edildiği platform yüksekliği olarak tanımlanmış ve her sporcu bu yükseklikte DJ uygulamasına tabi tutulmuştur. Ön test/son test tasarımı, ayrı ziyaretlerde uygulanmıştır. Referans çeviklik performansı, daha önceki bir seansta Lane Çeviklik Testi (LAT) kullanılarak değerlendirilirken, son test çeviklik ölçümleri, son ziyarette DJ tabanlı PAPE müdahalesinden hemen sonra kaydedilmiştir. İstatistiksel analizde bağımlı örneklemler için t-testi kullanılmış ve anlamlılık düzeyi $p<0.05$ olarak kabul edilmiştir. Bulgular, PAPE sonrası çeviklik süresinde %1,9 oranında istatistiksel olarak anlamlı bir iyileşme göstermektedir ($p=0.039$; ES=0.288). Çalışma, bireyselleştirilmiş PAPE yaklaşımlarının saha içinde uygulanabilirliğini vurgulamakta ve antrenman öncesi akut performans kazanımı açısından somut öneriler sunmaktadır.

Anahtar Kelimeler: Aktivasyon sonrası performans güçlendirme, Sıçrama, Reaktif kuvvet indeksi, Çeviklik

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## Introduction

In preparatory processes aimed at enhancing sports performance, warm-up has long been accepted as a fundamental practice. Warm-up protocols play a fundamental role both in the prevention of musculoskeletal injuries and in the enhancement of physical performance (Hartz et al., 2017). Particularly in disciplines requiring explosive power, high-intensity muscular activations performed at the end of the warm-up may positively contribute to performance by accelerating neuromuscular transmission (dos Santos Silva et al., 2023; Seitz & Haff, 2016; Wilson et al., 2013). This acute performance enhancement is defined in the literature as post-activation performance enhancement (PAPE) and occurs following a short-term, high-intensity muscular activity (Cuenca-Fernández et al., 2017). Although the term post-activation potentiation (PAP) has historically been used to describe increases in muscle twitch force following a conditioning contraction, recent literature distinguishes it from PAPE. PAP refers to a short-lived (<3 min) increase in evoked muscle force, primarily attributed to myosin light chain phosphorylation in type II fibers, whereas PAPE represents a longer-lasting (6–10 min) improvement in voluntary performance resulting from mechanisms such as elevated muscle temperature, increased muscle water content, and enhanced neural activation (Blazevich & Babault, 2019).

The effect of PAPE may vary depending on parameters such as the type of exercise performed, its intensity, and the recovery period. It is particularly emphasized that plyometric exercises offer an effective and applicable strategy for PAPE (Al Kitani et al., 2021; de Poli et al., 2020). These exercises enhance neuromuscular activation by targeting type II muscle fibers (Maloney et al., 2014) and can be easily integrated into the field since they do not require complex equipment. Unlike heavy resistance exercises, plyometric-based applications induce less fatigue, and the PAPE effect may emerge within a shorter period (<4 minutes) (Seitz & Haff, 2016; Zagatto et al., 2022).

Drop jump (DJ) exercises, which are included among plyometric exercises, enhance the muscles' capacity for strength and speed production by activating the stretch-shortening cycle (SSC) (Bomfim Lima et al., 2011; de Poli et al., 2020). In this context, DJ protocols are frequently preferred as preparatory strategies for high-intensity activities such as jumping, sprinting, and throwing (Maloney et al., 2014; Seitz & Haff, 2016). To enhance the effectiveness of DJs, it is recommended that jump height be determined individually and evaluated through performance indicators such as the reactive strength index (RSI) (Byrne et al., 2010). RSI is used as an indicator of explosive power capacity by representing the efficiency of the transition from the eccentric phase to the concentric phase (Flanagan et al., 2008; Markwick et al., 2015). In the literature, it has been shown that DJ protocols designed on the basis of RSI values provide significant performance improvements across different athletic disciplines, including runners, long jumpers, and throwers (Boullosa et al., 2020; dos Santos Silva et al., 2023; Terzis et al., 2009).

Basketball is a team sport based on explosive power, characterized by frequent repetitions of high-intensity sprinting, jumping, change-of-direction, and lateral movements. It has been reported that lateral movements alone account for approximately 20% of the total distance covered during a match (Ben Abdelkrim et al., 2010; Gál-Pottyondy et al., 2021). This situation demonstrates that agility performance is one of the key factors determining the course of the game. However, with the accumulation of fatigue during a match, a decline may be observed in the muscles' capacity to produce force in a short time. Therefore, strategies implemented prior to competition that aim to provide rapid performance enhancement are of importance for increasing on-court efficiency.

There are studies investigating the effects of drop jump-based PAPE on sprint performance (Al Kitani et al., 2021; Bomfim Lima et al., 2011; Zagatto et al., 2022) and jump performance (Bomfim Lima et al., 2011; Chen et al., 2013; dos Santos Silva et al., 2023), as well as studies examining its influence on anaerobic capacity (de Poli et al., 2020).

Moreover, different PAPE protocols have also been investigated in terms of their effects on change-of-direction (CoD) performance (Cengizel & Şenel, 2025; Gautam et al., 2024; Genç et al., 2025). However, findings in the literature regarding the effects of PAPE on agility and change-of-direction performance remain inconsistent. Some studies have reported significant improvements in agility or sprint times following PAPE protocols (Bomfim Lima et al., 2011; Genç et al., 2025; Zagatto et al., 2022), whereas others have found minimal or non-significant changes depending on the type of conditioning activity, rest interval, and population characteristics (Al Kitani et al., 2021; Cengizel & Şenel, 2025; Seitz & Haff, 2016; Wilson et al., 2013). These inconsistencies highlight the need for further investigation into individualized PAPE applications, particularly in sport-specific contexts such as basketball, where agility is a critical performance determinant.

As mentioned above, although PAPE has been widely studied in relation to sprinting and jumping performance, research focusing specifically on agility performance in basketball remains limited. In light of these inconsistent findings, further research applying individualized PAPE protocols is warranted to clarify their acute effects on agility performance. Therefore, this study aimed to investigate the acute effects of an individualized jump-based PAPE protocol, tailored according to individual RSI scores, on agility performance in male basketball players, with the hypothesis that RSI-based DJ applications would significantly enhance agility performance.

## Method

### *Research Design*

The study was conducted using a within-subjects repeated measures design, and all participants attended the sports hall on four separate occasions. To minimize potential fatigue effects, a 48-hour rest interval was provided between visits. All tests were performed at the same time of day in order to control for performance variability due to circadian rhythm. During each visit, a standardized warm-up protocol was applied, consisting of 10 minutes of general basketball warm-up followed by 5 minutes of dynamic mobilization.

The first visit was conducted to collect demographic information, provide participants with detailed explanations about the study, and obtain their written informed consent. During this visit, a familiarization session for the Lane Agility Test (LAT) and DJ protocols was performed. The second visit was dedicated to baseline measurements, in which the athletes' LAT performance times were recorded. Each athlete was given three attempts with a three-minute rest between trials, and the best score was recorded as the reference value. During the third visit, each participant's individual optimal DJ height was determined. Based on DJ attempts performed from 60 cm, 75 cm, and 90 cm platforms, the jump height corresponding to the highest RSI value was identified as the optimal height. The fourth and final visit included the implementation of the PAPE protocol followed by the LAT. After completing the standardized warm-up protocol, participants performed five repetitions of the DJ protocol at their predetermined optimal height, and following a four-minute passive rest period, the LAT was administered (Figure 1). All sessions were conducted in the same indoor sports hall, and participants wore similar athletic clothing and basketball shoes to ensure consistency across measurements. The same sequence of visits and procedures was followed for all participants to maintain methodological consistency. All participants completed the entire intervention protocol without any adverse events or injuries.

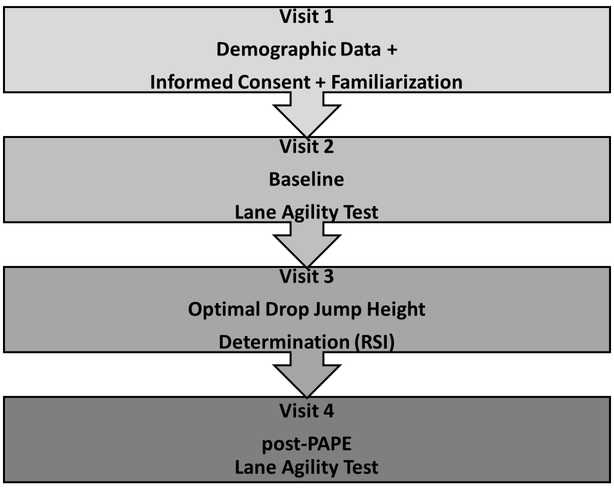


**Figure 1.** Flowchart of the study design illustrating the four laboratory visits

### *Research Group*

The required sample size was determined a priori using G*Power (version 3.1., University of Düsseldorf, Germany). We based our estimation on the PAPE effects reported in two recent DJ–based studies (Wu et al., 2023; Yang et al., 2024), which observed medium-to-large effects on jump performance (partial $\eta^2 \approx 0.21–0.22$) in trained athletes. Considering that these values correspond to a large effect size for a pre–post comparison ($dz \approx 0.80$), an a priori power analysis for a paired t-test (Means: difference between two dependent means, two-tailed, $\alpha=0.05$, power=0.80) indicated that a minimum of 15 participants would be required. To account for potential dropouts and to increase external validity, we recruited 20 sub-elite male basketball players, which provides statistical power greater than 0.90 to detect a PAPE effect of similar magnitude. All participants were sub-elite male basketball players competing in local clubs and engaged in regular team training under the supervision of certified coaches. The inclusion criteria were as follows: (a) being a licensed participant in basketball competitions, (b) engaging in regular basketball training at least five days per week, (c) having at least one year of strength training experience, and (d) possessing a minimum of five years of basketball experience. All participants had similar strength training backgrounds, having engaged in structured resistance training for at least one year. Athletes who had sustained injuries or undergone surgical operations in the lower or upper extremities within the past six months were excluded from the study.

### *Ethical Statement*

Prior to participation, all athletes were informed about the research and signed a written informed consent form. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Commission of Gazi University with dated 15/04/2025 and numbered 06.

### *Procedures*

System checks and zero verification of all measurement devices were performed before each testing session to ensure measurement accuracy. All measurements were performed and supervised by the same experienced investigator to ensure consistency across sessions. Standardized verbal encouragement was provided to all participants during each test to ensure maximal effort. Height and body mass measurements of each participant were performed during the first visit. Height was measured using a stadiometer with a precision of ± 0.1 cm (SECA 213, Germany), and body mass was assessed with a scale accurate to ±0.1 kg (SECA Colorata 760, Germany). During the measurements, participants wore light sports clothing and were barefoot.

*Lane Agility Test (LAT)*

LAT was conducted on a half-court using standard basketball court lines. A recent study demonstrated that the LAT is a reliable and valid test for evaluating agility in basketball players, showing excellent internal consistency (Cronbach's α=0.93–0.97) and high test–retest reliability (ICC=0.83–0.93) in junior basketball players (Selaković & Krneta, 2020). Participants positioned themselves at the waiting line, which was placed 50 cm behind the starting line. The test began once the participant indicated readiness. During the test, participants performed a forward sprint in the direction of arrow 1, a lateral shuffle in the direction of arrow 2, a backpedal in the direction of arrow 3, lateral shuffles in the directions of arrows 4 and 5, a forward sprint in the direction of arrow 6, another lateral shuffle in the direction of arrow 7, and finally a backpedal in the direction of arrow 8 (Brown, 2012). Participants completed the test by reaching the starting point (Figure 2). Throughout the test, all changes of direction were performed while maintaining a constant body orientation, with participants' faces directed in the same direction at every stage. Performance times were measured with millisecond precision using a photocell timing system (Newtest Powertimer 2000, Newtest Oy, Oulu, Finland) positioned at the start and finish lines. A study assessing the day-to-day test–retest reliability of this system reported excellent reliability across distances of 10 m (ICC=0.85), 20 m (ICC=0.95), and 30 m (ICC=0.97), with coefficients of variation below 3.2% and no significant systematic bias between test sessions (Shalfawi et al., 2011). Each participant was allowed three valid attempts with a three-minute rest between trials, and the best time achieved was recorded in seconds for analysis.

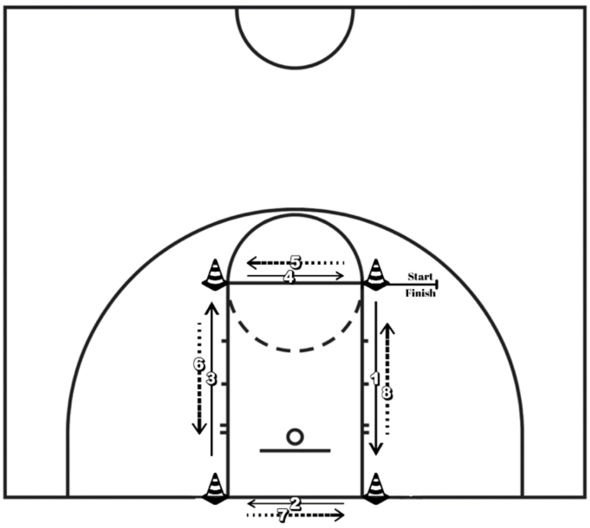


**Figure 2.** Schematic representation of the Lane Agility Test (LAT) used in the study. The sequence of movement patterns is indicated by the numbered arrows: forward sprint (1, 6), lateral shuffle (2, 4, 5, 7), and backward running (3, 8)

*Reactive Strength Index*

To determine the individual optimal DJ height, athletes performed DJ trials from 60 cm, 75 cm, and 90 cm platforms. Participants executed three DJs from each height with a three-minute rest between attempts. Jumps were performed by stepping forward with both feet from the platform and landing on the ground, aiming to achieve maximum jump height with the shortest possible ground contact time. The arms were not left free; instead, the hands were kept fixed on the hips. Jump height (cm) was measured using the Optojump Next system (Microgate, Bolzano, Italy), and RSI was calculated accordingly. The Optojump Next system has been shown to be a valid and reliable instrument for measuring temporal and reactive strength variables during jumping and hopping tasks, demonstrating excellent concurrent validity with a force platform (ICC>0.97) (Healy et al., 2016). The height at which the highest RSI value was obtained was determined as the participant's optimal DJ height (Byrne et al., 2010).

*Jump-based PAPE Protocol*

The jump-based PAPE protocol consisted of five DJ repetitions performed from the individually determined optimal height for each athlete. A 15-second passive rest interval was provided between repetitions (Chen et al., 2013). After completing the protocol, the athletes underwent a four-minute passive rest period, followed by the agility test. All procedures were carried out on the same indoor court surface, and the standardized warm-up protocol was applied prior to testing. During the tests, participants were verbally encouraged to exert maximal effort.

## *Data Analysis*

Descriptive statistics were reported as mean ± standard deviation and 95% confidence interval. The normality of data distribution was assessed using the Shapiro–Wilk test. Agility times before and after LAT were compared using a paired-samples t-test when normal distribution was confirmed, or the Wilcoxon signed-rank test when normality was not satisfied. The significance level was set at $p<0.05$. In addition, the magnitude of observed differences was calculated using Cohen's d effect size according to the following scale: trivial <0.2, small 0.2–0.5, moderate 0.5–0.8, large >0.8 (Cohen, 2013). Statistical analyses were performed using SigmaPlot 11.0 (Systat Software, Inc., San Jose, California, USA). All data were analyzed as collected, and no data points were removed or adjusted. No missing data were present, as all participants completed the full testing protocol.

## Findings

The mean age of the 20 male basketball players participating in the study was 22.1±2.1 years, the mean training age was 12.5±2.7 years, the mean height was 190.9±8.7 cm, and the mean body mass was 87.7±9.8 kg (Table 1).

**Table 1.** Characteristics of the participants

| | *Mean ± SD* | *95% CI* |
|---|---|---|
| Age (years) | 22.1 ± 2.1 | 21.2-23.0 |
| Training Age (years) | 12.5 ± 2.7 | 11.3-13.7 |
| Height (cm) | 190.9 ± 8.7 | 187.1-194.7 |
| Body Mass (kg) | 87.7 ± 9.8 | 83.4-92.0 |

The optimal DJ heights determined according to the individual RSI scores of the participants were evaluated in three groups. At the 60 cm DJ height (n=8), the mean jump height was 35.86±8.92 cm and the mean RSI was 1.50 ± 0.31. At the 75 cm DJ height (n=10), the mean jump height was 39.29±6.47 cm and the RSI value was 1.42±0.38. For the 90 cm DJ height (n=2), the mean jump height was 40.80±11.31 cm, and the mean RSI was 1.55±0.18 (Table 2, Figure 3).

**Table 2.** Distribution of RSI and jump height according to DJ height

| Height | n | RSI ($m.s^{-1}$) | | Jump Height (cm) | |
|---|---|---|---|---|---|
| | | mean ± SD | 95% CI | mean ± SD | 95% CI |
| 60 cm | 8 | 1.50 ± 0.31 | 1.29-1.72 | 35.86 ± 8.92 | 29.68-42.04 |
| 75 cm | 10 | 1.42 ± 0.38 | 1.19-1.66 | 39.29 ± 6.47 | 35.28-43.30 |
| 90 cm | 2 | 1.55 ± 0.18 | 1.30-1.80 | 40.80 ± 11.31 | 25.13-56.50 |

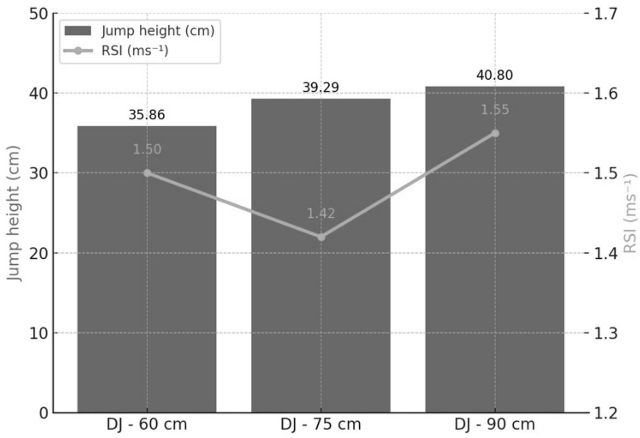


**Figure 3.** Mean values of jump height (cm) and reactive strength index (RSI, $m \cdot s^{-1}$) across three different drop jump (DJ) heights (60 cm, 75 cm, and 90 cm)

A statistically significant decrease was observed in the LAT scores performed after the individualized DJ protocol based on RSI values, when pre- and post-test results were compared (pre: 12.57±0.80 sec; post: 12.33±0.88 sec; $t(19)=2.214$, $p=0.039$). The effect size was at a small level (ES=0.288), and a 1.9% reduction in time was detected (Figure 4).

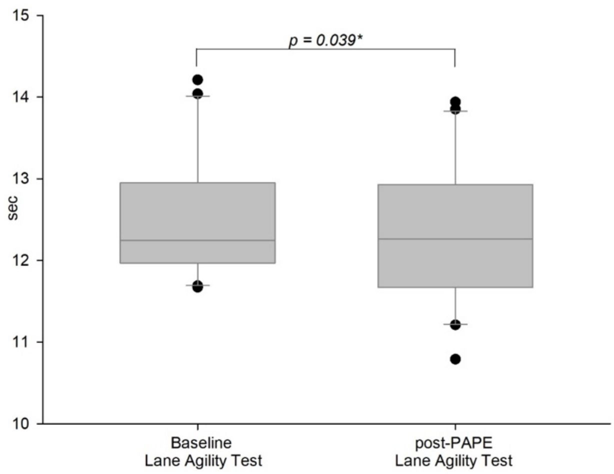


**Figure 4.** Comparison of Lane Agility Test scores before and after PAPE intervention

## Discussion

The aim of this current study was to investigate the acute effects of an individualized jump-based PAPE protocol, designed according to individual RSI scores, on agility performance in male basketball players. The key finding of the research was that following the individualized jump-based PAPE application based on RSI values, a statistically significant improvement in agility performance was observed, as evidenced by a time-based reduction in LAT scores. When pre- and post-test scores were compared, a 1.9% reduction in time was detected, and this difference was found to be statistically significant (pre: 12.57±0.80 s; post: 12.33±0.88 s; p=0.039). These findings support the hypothesis that an RSI-based individualized DJ protocol can provide acute improvements in agility performance.

This finding indicates that the effect of PAPE may not be limited only to linear performance indicators such as jump height (Kasicki et al., 2024; Vargas-Molina et al., 2021) or strength outputs (Garbisu-Hualde et al., 2023), but may also be effective on agility components such as change of direction, acceleration, and deceleration (Cengizel & Şenel, 2025). These findings are particularly meaningful for sports in which multiple changes of direction, acceleration–deceleration patterns, and reactive decision-making requirements frequently occur. In sports such as basketball, where agility is a key component, such acute performance improvements may provide in-game advantages. In the study by Kasicki et al. (2024), it was reported that the increase in muscle–tendon activation observed following PAPE applications contributed to situations requiring agility by accelerating movement patterns. Indeed, it is consistent with previous findings that plyometric-based applications enhance performance in the LAT, whereas resistance training programs that do not involve change-of-direction components do not provide a significant contribution in this regard (Morin et al., 2012; Yang, 2025). This may explain why a significant improvement was observed in the current study only with the jump-based PAPE performed after the warm-up routine. Similarly, it has been reported that the addition of a PAPE intervention to a warm-up routine (five repetitions of back squat at 80% of 1RM followed by a 3-minute passive rest) enhances CoD performance (Genç et al., 2025). It has also been shown that routine basketball training contributes positively to agility performance. After a four-month training period, an improvement of 0.11 s was observed in agility test time, and this development was interpreted particularly in relation to age-associated motor progressions (Cengizel et al., 2020). Interestingly, in the present study, a comparable improvement in agility performance was achieved acutely through a single warm-up session incorporating a PAPE protocol, indicating that short-term neuromuscular activation strategies may elicit effects similar to those observed after long-term training adaptations.

Given the individual variability in responses to PAPE interventions, there is a need for tools that assess athletes' reactive strength levels and elastic capacities. Gautam et al. (2024), emphasized that athletes' responses to PAPE applications may vary among individuals. On the other hand, RSI is known to reflect the speed of the eccentric–concentric transition and the production of explosive strength; therefore, it is used as a performance indicator to monitor athletes' explosive power potential based on the SSC (Flanagan et al., 2008; Markwick et al., 2015). Therefore, performing DJs at the most appropriate height according to individual RSI values allowed for providing the optimal stimulus to each athlete's neuromuscular system. This approach may offer a more effective and targeted application model compared to traditional one-size-fits-all PAPE protocols. The use of submaximal loads, which can effectively induce PAPE without causing fatigue, is of critical importance for athletes who aim to improve performance without the risk of injury or excessive strain (Kasicki et al., 2024).

## Limitation

Although the findings obtained are considerable, this study has certain limitations. One limitation of this study is related to the experimental design. Since all participants performed the control condition first and the PAPE condition on the final testing day, potential order or familiarization effects cannot be completely ruled out. Repeated exposure to the agility test may have led participants to perform slightly better during the final session, independent of the PAPE intervention itself. Although standardized familiarization and warm-up procedures were implemented to minimize this effect, future studies should adopt a randomized crossover design to eliminate potential order bias. Another limitation of this study is the absence of a parallel control condition, which may restrict the external validity and generalization of the findings. Future studies are recommended to include a parallel control group to strengthen causal inferences and enhance external validity. The research was conducted solely with male basketball players, and therefore the generalizability of the findings to female athletes or other sports disciplines is limited. Moreover, the analyses were performed without taking positional differences into account, which may have overlooked role-based variations that could influence agility performance. Furthermore, only the LAT was used in this study, and other subcomponents of agility (such as reactive agility and decision-making) were not evaluated. In addition to these limitations, the measurement of only the acute effect of the intervention restricts the ability to draw conclusions regarding the sustainability of the results. Future research should consider variables such as sex, sport discipline, and playing position to evaluate the long-term effects of PAPE protocols based on individualized DJ heights and to integrate outcomes with different agility tests. In this regard, there is a need for controlled and multicenter studies that investigate the long-term effects of RSI-based PAPE protocols on training planning, performance monitoring, and individualized loading strategies.

## Conclusion

This study examined the acute effect of a jump-based PAPE protocol individualized according to RSI values on agility performance in male basketball players. Following the intervention, a 1.9% reduction was detected in LAT time, and this difference was found to be statistically significant. This finding demonstrates that the PAPE protocol can enhance agility performance in the short term. The results indicate that PAPE applications structured according to individual characteristics may be incorporated into warm-up routines to improve agility-related performance, and that such protocols provide valuable recommendations for athletes, athletic performance coaches, and trainers in developing targeted and personalized preparation strategies.

## Practical Implications

The findings of this study indicate that implementing an individualized drop jump-based PAPE protocol, based on RSI values, can acutely enhance agility performance in elite male basketball players. This suggests that sport-specific warm-up strategies incorporating individualized neuromuscular activation may be used effectively to boost change-of-direction ability before training or competition. From a practical standpoint, athletic performance coaches and strength & conditioning professionals may benefit from using RSI to determine optimal DJ height for each athlete, ensuring a more precise and effective PAPE stimulus. Unlike generalized warm-up routines, this approach minimizes fatigue while targeting neuromuscular readiness, providing a practical solution for acute performance enhancement. In agility-demanding sports like basketball, where rapid acceleration, deceleration, and direction changes are frequent, even a small performance gain—as observed in this study (1.9%)—can offer a competitive edge. Additionally, using RSI-based PAPE interventions during pre-match routines may help compensate for match-day variability, enhance preparedness, and reduce injury risk associated with insufficient warm-up. Future studies should examine the long-term effects of RSI-based PAPE applications, consider athlete sex and playing position, and compare its efficacy with traditional warm-up protocols. Integrating this method into structured training plans may support individualized performance monitoring and progressive loading strategies in elite sport environments.

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*Conflict of Interest*

The authors declare no conflict of interest.

*Authors' contribution*

Research Idea: ÇÖC; Research Design: ÇÖC; Data Collection: ÇÖC; Data Analysis: ÇÖC; Writing: ÇÖC; Critical Review: ÇÖC.

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