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Post-Activation Performance Enhancement in Soccer Players: Effects of Different Contraction Types and Rest Intervals on Change of Direction Ability

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Abstract

Isometric and dynamic contraction protocols are commonly used in sports to achieve post-activation performance enhancement (PAPE). Although rest intervals in PAPE protocols have been widely investigated, the effects of different PAPE methods on performance across recovery intervals remain unclear. Therefore, this study aimed to examine the effects of post-activation potentiation induced by different contraction types on change-of-direction performance under varying rest durations. Twenty male soccer players (age: 20.9 ± 1.3 years; training experience: 7.6 ± 2.7 years; height: 176.9 ± 5.7 cm; body weight: 74.3 ± 7.5 kg) voluntarily participated in this study. The study used a randomized, crossover design, with 48-hour intervals over three non-consecutive days. On the first day, anthropometric characteristics and one-repetition maximum (1RM) knee extension performance were assessed. Following a standardized warm-up protocol, change-of-direction (CoD) test performance was recorded on the second and third days. After a 5-minute passive rest, participants performed either a dynamic (1 set of 3 repetitions at 90% 1RM) or an isometric (3 sets of 3 seconds, with 2-minute rest intervals) knee extension protocol. Subsequently, CoD tests were conducted at 15 seconds, 3, 6, 9, and 12 minutes post-activation. No significant main or interaction effects were observed for contraction type or recovery interval ($p > .05$). Furthermore, no significant differences in rest intervals were observed between the isometric and dynamic protocols ($F = 1.383$, $p = .255$, $\eta p2 = .061$). In conclusion, these results indicate that neither the isometric nor the dynamic exercise protocols produced a pronounced PAPE effect on CoD performance.

Keywords: *Change of Direction, Dynamic Contraction, Isometric Contraction, Post Activation Performance Enhancement, Soccer*

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INTRODUCTION

Soccer is characterized by varying running intensities, bilateral duels, jumping, change of direction (CoD) movements, coordination, and skill-based ball control, and it engages both the aerobic and anaerobic energy systems (Barnes et al., 2014; Stølen et al., 2005). The ability to rapidly change direction is considered a critical physical quality associated with success in youth soccer players (Brughelli et al., 2008; Hachana et al., 2013; Mujika et al., 2009), as it provides a significant tactical advantage (Chaouachi et al., 2014; Huijgen et al., 2010). Therefore, players must be able to perform effective CoD movements with and without ball possession (Jeffreys et al., 2018). One method commonly employed to enhance CoD performance is post-activation performance enhancement (PAPE) (Biel et al., 2023; Gautam et al., 2024; Marshall et al., 2019; Orjalo et al., 2020).

While classical post-activation potentiation (PAP) refers to myosin phosphorylation mechanisms at the muscular level, post-activation performance enhancement (PAPE) is defined as an acute improvement in performance following a moderate- to high-intensity muscular contraction (Tillin & Bishop, 2009). In PAPE, muscle strength and power can be temporarily enhanced, facilitating greater force production and acutely improving key performance components such as speed, strength, and change-of-direction (CoD) ability (Baker & Newton, 2009; Tillin & Bishop, 2009). The application of PAPE protocols in soccer has become increasingly prevalent, with numerous studies investigating their effects on sprinting (Akgül et al., 2024; Cabuk & Ince, 2025), jumping (Keskin et al., 2025; Till & Cooke, 2009), CoD performance overall athletic performance (Krzysztofik et al., 2025), and different contraction modalities (Chtara et al., 2018; Śliwowski et al., 2017).

PAPE has been shown to influence CoD performance in soccer. Petisco et al. (2019) demonstrated that performing five repetitions at 80% of one-repetition maximum (1RM) in the squat exercise significantly enhanced performance in a multi-component test battery involving jumping, sprinting, and CoD tasks among professional male soccer players, compared to a traditional warm-up without resistance. Similarly, Marshall et al. (2019) reported performance improvements -though not statistically significant- following three repetitions of 3-second isometric half-squats in elite rugby players across varying recovery durations.

In addition to exercise parameters, determining the optimal recovery period for maximizing the PAPE effect is critically important. Previous studies have examined a wide range of recovery durations -from 0 to 24 minutes- in an effort to optimize the potentiation response (Kilduff et al.,

2008; Titton & Franchini, 2017). A 4-minute recovery interval has frequently been utilized to elicit PAPE effects prior to vertical jump and sprint performance (Winwood et al., 2016). However, the findings regarding athletes' explosive performance remain inconsistent. For example, Kilduff et al. (2008) observed that an 8-minute recovery period was most effective for enhancing counter-movement jump (CMJ) performance in rugby players In contrast, Titton and Franchini (2017) found that a 1-minute rest interval was sufficient to significantly improve vertical jump height.

Although previous research has examined PAPE, few studies have simultaneously investigated the combined effects of contraction modality (isometric vs. dynamic) and recovery duration on change-of-direction (CoD) performance. Therefore, the present study aims to address this gap by examining how different PAPE contraction modalities influence CoD performance across various recovery intervals, thereby highlighting the investigation's novelty and practical relevance.

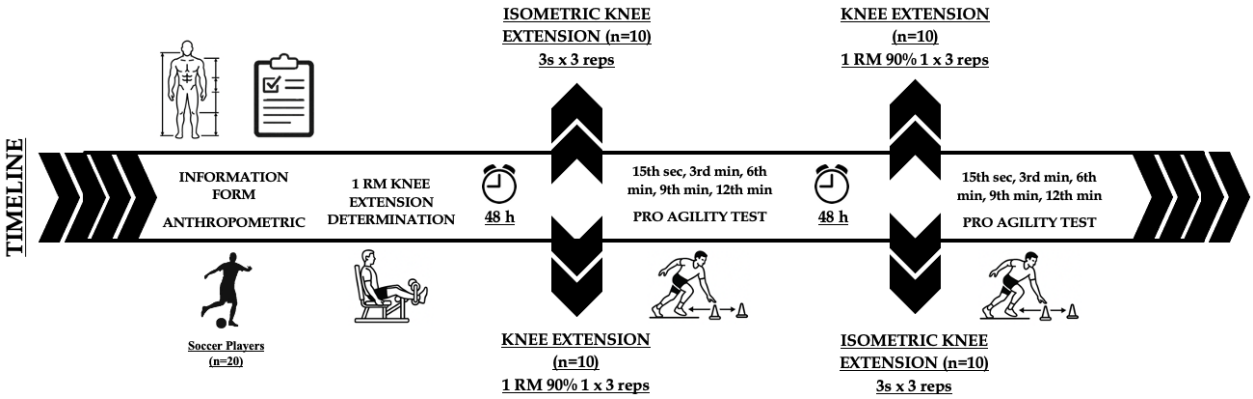
METHODS

Study Design

This study employed a randomized crossover design (Figure 1). Soccer players participated in two testing sessions conducted 48 hours apart. All tests were performed at the same time of day for all participants to minimize the influence of circadian rhythm on neuromuscular performance, strength, and power output (Martín-López et al., 2022). On the first day, after players were informed about the study procedures, descriptive data were collected using the InBody 270 device. Additionally, participants performed two submaximal practice trials of the Pro-Agility test to ensure familiarization with the testing procedure and to minimize potential learning effects. Following the anthropometric assessments, 1RM for knee extension was determined using a knee extension machine. On the second day, participants first completed a pre-test of the pro-agility test. After the assigned PAPE protocol was applied, the agility test was performed at 15 seconds, 3, 6, 9, and 12 minutes post-intervention. On the third day, the same procedures were repeated: participants performed a pre-test, followed by the PAPE protocol, and then repeated the agility test at the same time intervals. Participants were instructed to refrain from eating for 1.5 hours prior to each session. They were allowed to consume up to 500 mL of water during testing and were verbally encouraged throughout the agility assessments. To minimize fatigue, players were advised to avoid intense physical activity on the days preceding each session and to

ensure adequate carbohydrate intake to prevent a negative impact on repeated sprint performance.

Figure 1
Study Design



Participants

An a priori power calculation conducted using G*Power 3.1 for a repeated-measures ANOVA (within–between interaction; effect size F = 0.25, α = 0.05) indicated that a sample size of 18 participants would be adequate to detect moderate effects with 80% statistical power. Therefore, twenty male soccer players (age: 20.9 ± 1.3 years; training experience: 7.6 ± 2.7 years; height: 176.9 ± 5.7 cm; body weight: 74.3 ± 7.5 kg), all actively competing in the amateur league of Karabük region, voluntarily participated in this study. Participants were randomly assigned using an online randomization tool (www.randomizer.org) and completed both static and dynamic protocols. The study was conducted during the players' preseason preparation period. All participants provided written informed consent prior to participation. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of the University of Karabuk (2024/1786). The study was registered retrospectively on ClinicalTrials.gov under the identifier NCT06875505**.**

Procedure

Anthropometric Measurements

Participants' height was measured using a stadiometer (Holtain Stadiometer, England). The participants' body weight, fat percentage, and fat-free mass were measured using an InBody 270 body analysis device (Biospace, California, USA) following the manufacturer's instructions.

Warm-up Protocol

Participants performed a warm-up protocol in all conditions, which consisted of a 5-minute run at 9 km/h on a treadmill (Sprint Runner; Hoggan Health Industries, Draper, UT) followed by 3-minute whole-body light stretching exercises according to previous study (do Carmo et al., 2021).

Knee Extension One-Repetition Maximum (1RM) Determination Protocol

Following the initial warm-up protocol, the soccer players performed a standardized warm-up session consisting of five repetitions at approximately 50% of their estimated 1RM on a knee extension machine (Diesel Fitness D12, Turkey). This was followed by a preparatory phase, during which participants completed 1–2 sets of 2–3 repetitions at loads corresponding to approximately 60–80% of their estimated 1RM. Subsequently, players performed incremental single-repetition maximum (1RM) trials with progressively increasing loads until they were unable to complete the full range of motion. Rest intervals of 3–5 minutes were provided between each attempt to minimize fatigue. In accordance with the National Strength and Conditioning Association (NSCA) guidelines, participants were encouraged to reach their 1RM within 3 to 5 attempts to prevent excessive fatigue (Haff & Triplett, 2021).

Dynamic PAPE Protocol

A load corresponding to 90% of each participant's 1RM was applied during the knee extension exercise. Following a standardized warm-up, the protocol consisted of three consecutive repetitions without rest at the predetermined 90% 1RM load (Seitz et al., 2014). The exercise involved bilateral isometric knee extensions performed seated on a knee extension machine (Diesel Fitness D12, Turkey), with adjustments to accommodate individual limb lengths. At the beginning of each contraction, the knees were positioned at 90° of flexion, and the machine's lever arm was fixed accordingly. Participants were then instructed to generate maximal isometric force through knee extension until full extension at 180° (Lim & Kong, 2013). This protocol is consistent with previous studies reporting improvements in jumping and sprint performance (Till and Cooke, 2009; French et al., 2003; Rixon et al., 2007). Knee extension angles were monitored throughout the exercise using the 'My Mocap' application (Gençoğlu et al., 2023). Participants received verbal encouragement and were continuously reminded to maintain correct form.

Isometric PAPE Protocol

The isometric contraction protocol was performed on a knee extension machine (Diesel Fitness D12, Turkey) using a load corresponding to 90% of each participant's 1RM. Participants completed three sets of 3-second bilateral isometric contractions, with a 2-minute rest interval between sets. The exercise was executed in a seated position, adjusted individually for limb length, and conducted in a controlled manner. At the start of each contraction, the knees were positioned at 90° of flexion, with the machine's adjustable lever arm fixed at that angle. Participants were then instructed to exert maximal force during bilateral isometric knee extensions, continuing the effort until full extension at 180 °. This protocol aligns with previous studies reporting performance improvements in jumping and sprinting tasks (Till and Cooke, 2009; French et al., 2003; Rixon et al., 2007). During the exercise, knee extension angles were monitored using the 'My Mocap' application (Gençoğlu et al., 2023). Participants received verbal encouragement and were reminded to perform each contraction with maximal effort.

Pro-Agility Test Protocol

The Pro-Agility test was performed on a tartan surface using a dual-beam electronic timing gate system (SmartSpeed; VALD Performance, Brisbane, Australia). Baseline measurements were recorded 5 minutes prior to both the dynamic and isometric PAPE protocols. Following the applications, the first measurement was taken at 15 seconds, followed by 3-minute intervals (at 3, 6, 9, and 12 minutes; Seitz et al., 2014). To prevent cumulative fatigue and to isolate the time-dependent effects of PAPE, a single (1) maximal trial was performed at each specific time point. This approach was implemented to enhance the transparency, reliability, and reproducibility of the experimental procedures

Data Analysis

Data were analyzed using IBM SPSS Statistics 27 (IBM Corp., Armonk, NY, USA) and Microsoft Excel 2019 (Microsoft Corp., Seattle, WA, USA). The Shapiro-Wilk test was applied to assess the normality of data distribution. A repeated measures analysis of variance (ANOVA) with a 2 × 6 (condition × time) design was conducted for CoD measurements under the dynamic and isometric protocols. When significant effects were found, Bonferroni post hoc tests were performed to identify within-condition differences. Statistical significance was set at $p < 0.05$ for all analyses. Effect sizes were calculated using partial eta squared ($\eta p2$), interpreted according to Cohen's

guidelines as small (0.01), medium (0.06), and large (0.14) effects (Cohen, 1992). Confidence intervals were set at 95% and values below $p<0.05$ were considered statistically significant.

RESULTS

Table 1 presents the descriptive characteristics of the soccer players along with their corresponding 95% confidence intervals.

Table 1
Descriptive Characteristics of Soccer Players (n = 20).

Age (year)	Experience (year)	Height (cm)	Weight (kg)	BMI (kg/m²)	BFP (%)	1RM (kg)	Relative 1RM
20.9 ± 1.3	7.6 ± 2.7	176.9 ± 5.7	74.3 ± 7.5	23.7 ± 2.1	16.2 ± 3.7	114.7 ± 24.8	1.5 ± 0.3

Note. BMI: body mass index, BFP: body fat percentage.

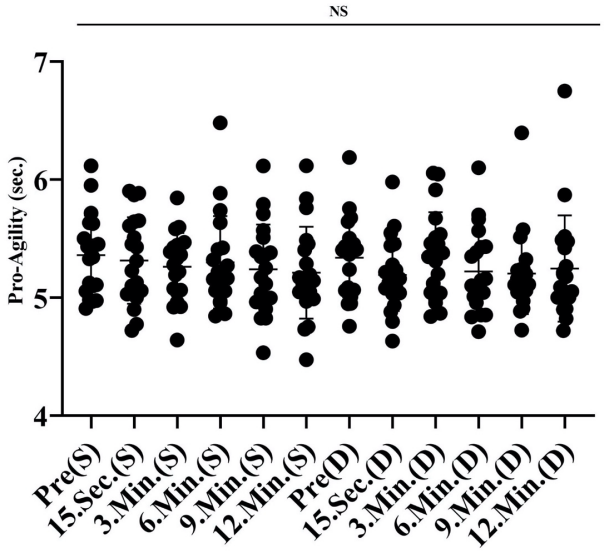
Table 2 presents the CoD speed values across six time points under both isometric and dynamic pre-exercise conditions. The analysis revealed no statistically significant differences in CoD performance across time within either the isometric or dynamic contraction conditions. Additionally, no significant differences were observed between the two contraction types ($F = 1.383$, $p = 0.255$, $\eta p2 = 0.061$). The mean CoD speed values remained relatively stable throughout the measurement period, ranging from 5.21 to 5.36 seconds for the isometric condition and 5.19 to 5.35 seconds for the dynamic condition. These findings indicate that neither pre-exercise protocol elicited a superior PAPE effect on agility performance.

Table 2
Comparison of the Effects of Different Rest Intervals on Change of Direction Speed in Dynamic and Isometric Contraction Conditions

	Conditions				ANOVA		
Time	Isometric Mean ± SD	(95% CI)	Dynamic Mean ± SD	(95% CI)	F	P	η_p^2
Pre-Test	5.36 ± 0.33	5.20 - 5.51	5.33 ± 0.33	5.18 - 5.49			
15. sec	5.31 ± 0.36	5.14 - 5.48	5.19 ± 0.30	5.04 - 5.48			
3. Min	5.26 ± 0.28	5.12 - 5.39	5.35 ± 0.36	5.18 - 5.53			
6. Min	5.29 ± 0.39	5.11 - 5.48	5.22 ± 0.35	5.05 - 5.38	1.383	0.255	0.061
9. Min	5.24 ± 0.38	5.06 - 5.41	5.20 ± 0.34	5.04 - 5.36			
12. Min	5.21 ± 0.38	5.02 - 5.39	5.24 ± 0.44	5.03 - 5.45			

Note. SD: Standard Deviation; F: F-statistic; CI: Confidence Interval; p: Probability value; η_p^2: Partial eta squared - effect size.

Figure 2
CoD Performance With Different Contraction Types and Time Points.



DISCUSSION

This study investigated the effects of two PAPE protocols-dynamic and isometric knee extension contractions on CoD performance at multiple recovery intervals (15 s, 3, 6, 9, and 12 min). The findings revealed no significant improvements in CoD performance across any time points, regardless of protocol. These results contribute to the ongoing debate regarding the effectiveness of PAPE strategies on agility-related tasks and highlight important considerations for the practical application of such methods. A recent systematic review by Li et al. (2023) concluded that while PAPE effectively enhances strength, power, and sprint-related outcomes, evidence for its impact on agility and flexibility is limited and inconclusive. The lack of significant findings in the present study reinforces this gap, suggesting that the translation of PAPE to CoD tasks may be less consistent than other performance measures.

Contrary to our findings, Toprak et al. (2022) reported significant improvements in CoD performance following both static and dynamic squat protocols in adolescent soccer players. While their results demonstrated performance benefits as early as two minutes post-activation, with peak improvements around the 8th minute and residual effects lasting up to 14 minutes, our study did not observe similar enhancements. This discrepancy may be explained by several methodological factors. Toprak et al. employed multi-joint squats at 85% of 1RM, whereas the present study used isolated knee extension contractions. The lack of multi-joint involvement in

our protocol may have limited the transfer of potentiation effects to the complex, multi-planar demands of CoD performance. These differences highlight that PAPE responses are highly task- and protocol-specific, emphasizing the importance of matching activation exercises to the performance outcome of interest.

Other studies have also demonstrated positive effects of heavy-load or moderate-intensity conditioning activities on agility and sprint performance. For instance, Sánchez-Sánchez et al. (2018) found that a PAP warm-up using ~90% 1RM squats improved repeated sprint ability in national-level soccer players, with smaller effects observed in regional players. Similarly, Petisco et al. (2019) observed that an 80% 1RM warm-up elicited the most consistent improvements across CoD, jumping, and sprint tasks, whereas 60% and 100% 1RM protocols were less effective or detrimental. These findings suggest that the choice of load is crucial, with moderate to heavy intensities often producing the most favorable outcomes. Our 90% isometric contractions may have produced excessive fatigue, offsetting potential potentiation effects.

From a physiological perspective, the detailed neuromuscular and biomechanical requirements of change-of-direction (CoD) performance may account for the lack of performance improvement in the current study. Rapid deceleration, eccentric strength, stretch-shortening cycle efficiency, and coordinated multi-joint force output at the hip, knee, and ankle joints are necessary for successful CoD activities (Harper et al., 2022). PAPE responses, on the other hand, are typically linked to processes including increased myosin regulatory light chain phosphorylation, improved motor unit recruitment, and greater neural drive, all of which boost the output of muscle force during future contractions. However, these potentiation mechanisms may transfer more effectively to linear or single-movement tasks such as jumping or sprinting than to complex agility movements that require rapid braking, directional control, and inter-muscular coordination (Blazevich & Babault, 2019). Because the conditioning activity used in the present study involved isolated knee extension contractions, the neuromuscular activation pattern may not have sufficiently replicated the multi-joint and multi-planar demands of CoD performance. Consequently, the potentiation stimulus may have been too localized to influence the coordinated movement patterns required during directional changes meaningfully. This highlights the importance of biomechanical and neuromuscular specificity when designing PAPE protocols to improve agility-related tasks.

Another important methodological component is the repeated CoD assessments conducted within the same testing session. Since participants completed several CoD trials across a range of recovery durations (15 s, 3, 6, 9, and 12 min), the test's repeated execution may have affected subsequent performance outcomes. A learning effect or fatigue from repeated sprint or agility tests performed in a short period may mask potentiation responses. In particular, growing familiarity with the movement pattern may lead to incremental increases that are independent of the conditioning activity. However, repeated high-intensity workouts may lead to neuromuscular fatigue, which could counteract the potential benefits of PAPE.

Timing also plays a critical role in PAPE responses. Mola et al. (2014) reported that optimal recovery windows varied considerably among individuals, with responders showing potentiation at 4 to 16 minutes post-activation, while nonresponders showed no improvement. Similarly, Ishak et al. (2023) demonstrated that a 12-minute recovery period following an 85% 1RM squat was most effective for enhancing agility, sprint, and jump performance in both male and female athletes. The current study's assessment across intervals up to 12 minutes did not identify performance gains, suggesting that either longer recovery windows may be needed or that the isolated conditioning exercise was insufficient to elicit meaningful potentiation.

Finally, Pauli et al. (2024) demonstrated that while acute effects of PAPE may be modest, chronic neuromuscular training programs incorporating PAPE can lead to long-term improvements in strength and agility. This raises the possibility that isolated acute protocols, such as those used in our study, may not be sufficient to elicit immediate performance benefits but could contribute positively when integrated into long-term training strategies. In line with our findings, the present study reinforces that isolated single-joint knee extension contractions may not elicit meaningful PAPE responses for CoD performance, in contrast to multi-joint, sport-specific, and optimally loaded protocols reported in previous research. These results underscore the importance of exercise specificity, appropriate load selection, and consideration of recovery intervals when designing PAPE interventions. Future studies should further explore individual responsiveness and protocol optimization to clarify the mechanisms underlying PAPE effects on agility-related performance.

This study is not without limitations. The small sample size may have reduced the statistical power to detect subtle protocol differences. Only acute effects were examined, leaving long-term adaptations or cumulative training benefits unaddressed. Although a crossover design was

implemented, individual differences in recovery capacity, fitness level, and responsiveness to PAPE protocols could still have influenced the results. Finally, CoD performance was assessed using a specific test, which may not fully capture the multidimensional nature of agility in sport contexts. Future studies with larger cohorts, more ecologically valid CoD assessments, and diverse athletic populations are warranted to clarify the potential role of different PAPE strategies in enhancing agility performance.

CONCLUSION

Overall, the results of this study indicate that during the recovery intervals under investigation, neither dynamic nor isometric knee extension contractions clearly improved CoD performance. However, considering the methodological features of the study, such as the use of an isolated single-joint conditioning exercise, a limited sample size, and the evaluation of only acute responses, these findings should be taken cautiously. Therefore, the lack of substantial performance improvement in this study does not necessarily mean that PAPE techniques are not useful for enhancing CoD performance in general. Instead, the results show that no significant potentiation was observed under the specific experimental conditions used in this investigation.

PRACTICAL IMPLICATIONS

From a practical standpoint, the results of this study suggest that isolated knee extension contractions, whether dynamic or isometric, may not provide meaningful benefits for CoD performance in applied sport settings. Coaches and practitioners aiming to enhance agility through PAPE should consider selecting conditioning activities that are biomechanically and neuromuscularly more similar to the target performance task, such as loaded squats, plyometric exercises, or CoD-specific drills. Moreover, attention should be paid to individual variability in PAPE responsiveness, as some athletes may benefit more than others depending on their training status, muscle fiber composition, and recovery capacity. These insights can help guide the design of warm-up and activation strategies, ensuring they are both sport-specific and performance-relevant.

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Authors' Contribution

The conceptualization and methodology of the study were conducted by first, second, and last authors. Data collection was performed by first, third, fourth, and fifth, while the data analysis was carried out by sixth and second authors. The drafting of the article was completed by second author, and the final revisions were made by first and sixth authors. All authors have read and agreed to the published version of the manuscript.

Declaration of Conflict Interest

The authors declare no conflicts of interest.

Ethics Statement

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of the University of Karabük, Turkiye (2024/1786). Study was registered retrospectively with Clinicaltrials.gov under the identifier NCT06875505.

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