Recovery effect of turmeric (curcuma longa l.) and black pepper (piper nigrum) in combination on futsal players

Efecto recuperador de la cúrcuma (curcuma longa l.) y la pimienta negra (piper nigrum) en combinación en jugadores de futsal

Authors

Agung Dwi Juniarsyah[1]
Tommy Apriantono[1]
Neng Fisheri Kurniati[1]
Bagus Winata[1]
Muhamad Fahmi Hasan[1]
I Ketut Adnyana[1]
Yudhi Teguh Pambudi[2]

[1] Bandung Insitute of Technology (Indonesia)
[2] University of Jenderal Soedirman (Indonesia)

Corresponding author:
Tommy Apriantono
tommy@itb.ac.id

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Abstract

Introduction: There is considerable interest in understanding the physical demands of futsal players to achieve optimal performance.
Objective: This study aimed to investigate the effects of curcumin and piperine supplementation on the performance of futsal players after two consecutive intensive matches.
Methodology: A randomized, double-blinded, placebo-controlled design was used in this study. Sixteen amateur futsal players participated and were randomly assigned to two equal groups. The experimental group received curcumin 100 mg + piperine 5 mg, while the placebo group received 105 mg of microcrystalline cellulose. Two matches were played consecutively 24 hours apart (2 × 20 minutes). VO2max was assessed seven days before the first match, while internal load heart rate was evaluated during both matches. To examine players' recovery, CMJ and sprint performance were measured at baseline, 24 hours after the first match, and at 24, 48, and 72 hours after the second match.
Results: VO2max and heart rate were similar between both groups, indicating comparable fitness levels and internal load heart rate. Significant differences were found in CMJ ($p<0.05$) and sprint times ($p<0.05$) between the experimental and placebo groups at 24, 48, and 72 hours after the second match.
Discussion: The results suggest that curcumin and piperine supplementation effectively enhance recovery by reducing muscle fatigue and preserving neuromuscular performance after matches.
Conclusions: The combination of curcumin and piperine enhances recovery and helps maintain performance in futsal athletes with demanding competition schedules.

Keywords

Curcumin; futsal; performance; piperine; recovery; supplementation.

Resumen

Introducción: Existe un gran interés en comprender las demandas físicas de los jugadores de futsal para alcanzar un rendimiento óptimo.
Objetivo: Este estudio tuvo como objetivo investigar los efectos de la suplementación con curcumina y piperina en el rendimiento de los jugadores de futsal después de dos partidos consecutivos de alta intensidad.
Metodología: Se empleó un diseño aleatorizado, doble ciego y controlado con placebo. Participaron dieciséis jugadores amateurs de futsal, quienes fueron asignados aleatoriamente a dos grupos iguales. El grupo experimental recibió 100 mg de curcumina + 5 mg de piperina, mientras que el grupo placebo recibió 105 mg de celulosa microcristalina. Se llevaron a cabo dos partidos en días consecutivos con 24 horas de diferencia (2 × 20 minutos). El VO2max se evaluó siete días antes del primer partido, mientras que la frecuencia cardíaca de carga interna se registró durante ambos encuentros. Para evaluar la recuperación de los jugadores, el rendimiento en CMJ y esprint se midió en la línea base, 24 horas después del primer partido, y a las 24, 48 y 72 horas posteriores al segundo partido.
Resultados: No se encontraron diferencias significativas en el VO2max ni en la frecuencia cardíaca entre los grupos, lo que indica niveles de condición física y carga interna similares. Se observaron diferencias significativas en el rendimiento del CMJ ($p<0.05$) y los tiempos de esprint ($p<0.05$) entre el grupo experimental y el grupo placebo a las 24, 48 y 72 horas después del segundo partido.
Discusión: Los resultados sugieren que la suplementación con curcumina y piperina mejora eficazmente la recuperación al reducir la fatiga muscular y preservar el rendimiento neuromuscular después de los partidos.
Conclusiones: La combinación de curcumina y piperina favorece la recuperación y ayuda a mantener el rendimiento en jugadores de futsal que siguen calendarios de competición exigentes.

Palabras clave

Curcumina; fútbol sala; actuación; piperina; recuperación; suplementación.

Introduction

Futsal is a sport played around the world by men and women, in amateur and professional leagues, and by young and older people (Barbero-Álvarez et al., 2008). The number of practitioners playing both competitively and recreationally has increased in recent years (Méndez-Dominguez et al., 2022). When competing, futsal players cover an average distance of 3,000-4,500 m in a single match (Barbero-Álvarez et al., 2008). Futsal players perform a sprint every 79 s during regular games and usually cover 121 (105-137) m/min and spend 5% (1-11 m) and 12% (3.8-19.5 m) of the total playing time doing sprinting and high-intensity running, respectively (Castagna et al., 2009). Futsal can be classified as an intermittent high-intensity sport with frequent short sprints (Beato et al., 2017). Intermittent sport is defined as a sport in which players stop and start often and for short periods. Recent studies reported that players experienced cardiovascular stress of more than 85% of their maximum heart rate (HRmax) during more than 80% of game time (Ayarra et al., 2018). Futsal players need to have well-developed speed, agility, muscular strength, and power to perform specific futsal skills (e.g., shooting, dribbling, passing, ball recovery) and movements (e.g., acceleration, deceleration, sprinting, change of direction, jumping) (Álvarez et al., 2009; Spyrou et al., 2020). In addition, recovery strategy is an important factor that has to be considered to help players play optimally in every match.

There is a considerable interest in the physical needs of futsal players so that optimal abilities can be obtained. However, there are many active debates about the physiology of futsal players. For example, de Moura (2012) reported that the requirement of playing two to four matches per week adds to the stress on players, thus increasing their susceptibility to injury and impairing their performance due to fatigue, muscle injury, and inflammation (de Moura et al., 2012). The Spanish Futsal League plays one match/week, but during the Futsal World Cup, players play approximately one match every two to three days (López-Segovia et al., 2019). As a result, futsal puts athletes at high risk of physical stress, muscle injury, and fatigue, especially in high-level futsal players (Martinez-Riaza et al., 2017). Strenuous physical activity involving external muscle contractions and significant mechanical stress, along with the release of cytokines and the enzymes creatine kinase (CK) and lactate dehydrogenase (LDH), is a sign of muscle damage (Sedaghat et al., 2021) . Futsal players can suffer injuries due to muscle fatigue, physical contact, or collisions between players (Miloski et al., 2016).

Several studies have been conducted to overcome these conditions. Some of the strategies that have been implemented to reduce the impact of muscle injuries include active passive recovery methods (Perrier-Melo et al., 2021), cold water immersion techniques (Martínez-Guardado et al., 2020), protein consumption (Pasiakos et al., 2015), and the use of herbal-based supplements (Askari et al., 2020). Additionally, antioxidant supplementation, such as n-3 fatty acids and curcumin, may be a useful addition to the health management of athletes (de Moura et al., 2012).

Several investigations have reported positive results for curcumin in aiding exercise recovery (Mallard et al., 2021; Nanavati et al., 2022). The anti-inflammatory properties of curcumin have a positive effect on several diseases (Li et al., 2019). Curcumin can also improve the health of active individuals as curcumin was shown to attenuate inflammation to prevent muscle damage (Sahin et al., 2016), reduce pain associated with damage onset muscle soreness (DOMS), and positively recover muscle performance (Nicol et al., 2015). Reducing DOMS can be crucial in sports, because muscle soreness can decrease performance in subsequent exercise sessions (Nanavati et al., 2022). Curcumin has anti-inflammatory and antioxidant properties that can help reduce DOMS, which could improve performance (Fernández et al., 2020). Despite its therapeutic potential, curcumin has notably low bioavailability (Mallard et al., 2021). Co-administration of curcumin with piperine, a bioactive constituent of black pepper, has been reported to increase curcumin bioavailability by up to 2000% in humans (Delecroix et al., 2017). Oral supplementation is a useful recovery strategy to prevent injuries and perform optimally in every match. In this study, the combination of curcumin-piperine supplementation was hypothesized to enhance recovery and maintain the performance of futsal players.

The high-intensity nature of futsal matches comes from high-intensity futsal movements (e.g., sprints, jumps, direction changes). To efficiently perform specific high-intensity futsal movements, the ability of the lower body to exert power at high speeds (i.e., power output) is crucial. In general, this ability is indirectly assessed by various jumping and sprinting performance tests, with the countermovement jump (CMJ) and 5-20 m run being the most frequently used tests (Delecroix et al., 2017; Doeven et al.,

2018; Naser et al., 2017). The repetition of high-intensity movements by futsal players will cause the risk of injury when recovery is inadequate. In the Indonesian Futsal League, players are required to play two consecutive matches (with 24 hours of rest between the matches), and the risk of injury will be even higher.

Research conducted by Pedrinelli (2015) showed that more than 50% of futsal players consume nutritional supplements during the competition period. Most of the substances contained do not have proper scientific evidence regarding their safety and efficacy. Furthermore, based on the International Olympic Committee's investigation, 14.8% of the 634 dietary samples tested contained anabolic androgenic steroids, although these substances were not listed on the product labels, posing adverse risks for players (Wei a Wang, 2023). Since there are many nutritional supplements with questionable safety and efficacy, further research is required to study the effectiveness of nutritional supplements for futsal players. Therefore, this study aimed to examine the effect of curcumin and piperine supplementation on the recovery of futsal players with tight match schedules. To our knowledge, there has been no research investigating the effect of curcumin-piperine combination on performance improvement in amateur futsal players, especially with two matches conducted with a 24-h gap to the next match. By exploring the potential benefits of the combined supplementation, athletes, coaches, and sports practitioners can obtain evidence-based recommendations to improve players' physical abilities, reduce the negative impact of intense training, and maintain players' peak performance levels.

Method

Participants

The participants of this study were sixteen amateur male futsal players who played in the field position. Inclusion criteria were members of Bandung Futsal League championship, age ranged 18-23 years, had been playing futsal for at least 3 years, practiced for 7-10 hours per week, non-smokers, healthy, and had no injuries. Exclusion criteria of this study were goalkeepers, smokers, had injuries, had consumed an investigational product within the previous 10 days, took anti-inflammatory/analgesic drugs in the last two weeks, or used any ergogenic aid in the last two weeks before the study. The sample category was classified into the trained/developmental athlete population. The study procedures and potential risks were explained to the participants, and written informed consent was obtained before the study began. The research plan was reviewed and authorized by the Institutional Ethics Committee (IEC) (No. 03/KEPK/EC/IX/2022), which referred to the Helsinki Declaration at Polytechnic Kesehatan Kemenkes Bandung, Indonesia.

Procedure

Curcumin and Piperin Supplement

Ganesh Fit (GF; PT Sarakamandiri Semesta, Bogor) was a supplement capsules product that contained 100 mg of curcumin and 5 mg of piperine. GF was approved by the Indonesian Food and Drug Authority (BPOM) and a registered product license (TR. 223018181).

Measures

Countermovement Jump

In the CMJ protocol, the participants started from a static standing position and were instructed to perform a descent phase, free knee flexion, followed by a rapid and vigorous extension of the lower limb joints (ascent phase). Participants were asked to jump as high as possible, with a trunk as vertically as possible, and with hands remaining on the hips. Jumping performance was performed using a contact mat system (Takei 5414). Two attempts were made by each participant, followed by a rest period of ~15 seconds. The CMJ was recorded in cm at baseline, 24 h after the first match, 24 h after the second match, 48 h after the second match, and 72 h after the second match (Figure 1).

Sprint

Five minutes after the jumps, all players performed 2 maximal 20-m sprints with a 90-second passive rest interval between each sprint. The 20-m sprint test was conducted using a precise measurement

system comprising two sets of double infrared reflex photoelectric cells, specifically the Smartspeed system (Fusion Smartspeed Pro). These photoelectric cells were securely affixed to tripods and positioned at a height of 1.2 m, spaced 1.5 m apart in pairs, with timing gates placed at the 0 m (i.e., starting gate) and 20 m marks (i.e., finishing gates). All sprinting tests were conducted in an indoor court, thus eliminating any potential negative effects of the environmental conditions. This methodology ensured accuracy and consistency in evaluating the players' sprint performance. The sprint time was recorded in seconds at the same time points as the CMJ measurements, i.e., baseline, 24 h after the first match, 24 after the second match, 48 h after the second match, and 72 h after the second match (Figure 1)

Internal load

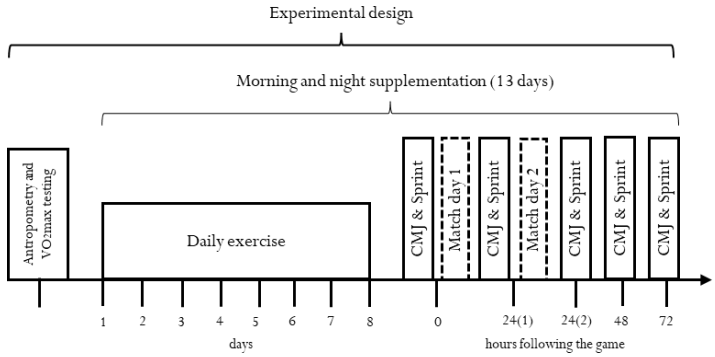
During the match, players used a heart rate monitor. Heart rate was used to measure internal load responses during the match and was recorded using the Team Polar system (Polar, Finland) M430. Peak heart rate was the highest value achieved during match-play, and average heart rate was taken for the whole 2x20-minutes matches without any substitution.

Experimental Design

A randomized, double-blinded, placebo-controlled design was used in this study to examine the effects of GF on the performance of futsal players. The study was conducted over a period of two weeks (Figure 1). One week before the match, and starting to take supplements, VO2max was measured using the Yoyo Intermittent Test Level 1 (Yo-Yo IR1) (Krustrup et al., 2003).VO2max data was collected to determine the homogeneity of all participants. Then, the body weight and body mass index of each participant was measured using a Karada HBF-375 scale (Omron, Matsusaka, Japan). Meanwhile, the participants' height was measured with a Seca model HR-222 stadiometer. The data collection was observed directly by the researchers.

At the beginning of the first week, all participants underwent a daily exercise routine for seven days before the first match with a duration of 60-90 minutes/exercise. All participants took twice daily capsules of either the supplement or placebo. The experimental group consumed GF two hours before morning exercise and before bed at night. Meanwhile, the placebo group (PLA) consumed capsules containing 105 mg of microcrystalline cellulose with the same schedule as the GF group. After the 7-day intervention period (week 1), all participants underwent their first futsal match following the rules set by FIFA to induce muscle damage on the first and second match days. The first match (9 days after the intervention) took place at 3 p.m. on a futsal pitch with an average temperature of 28 ± 2°C for the duration of the match. The second match was carried out at the same time and average temperature as the first match. During the matches (on days 9 and 10), the participants consumed the supplement twice daily. They continued to take the capsules until day 13.

Figure 1. Experimental design of the study.



0: baseline before the first match starts; 24(1): 24 hours after the first match; 24(2): 24 hours after the second match; 48: 48 hours after the second match; 72: 72 hours after the second match; CMJ: countermovement jump; VO_2max: volume oxygen maximal.

Data analysis

The normal distribution of parameters was assessed using the Kolmogorov-Smirnov test. For normally distributed parameters, one-way analysis of variance (ANOVA) was used to compare differences between groups, followed by Tukey's post hoc test for pairwise comparisons. Statistical significance was

set at p<0.05. For parameters that were not normally distributed, the Kruskal Wallis non-parametric test was used, and if there were significant differences, the Mann-Whitney U test was used for pairwise comparisons. All data was presented as mean ± standard deviation (SD). Statistical analysis was performed using SPSS 24.0 (IBM Corp, Armonk, NY, USA).

Results

Table 1 presents the anthropometric characteristics of the study participants, namely age, height, weight, and body mass index. The anthropometric characteristics in this study followed a normal distribution. No significant differences were observed between the PLA and the GF groups at baseline.

Table 1. Anthropometric Characteristics of PLA and GF Groups

Variable	PLA (n=8)	GF (n=8)	P value
Age (years)	21 ± 1.20	20.50 ± 1.20	1.000
Height (cm)	166.38 ± 4.41	166.88 ± 5.17	0.283
Weight (kg)	60.69 ± 7.59	61.60 ± 5.18	0.345
Body Mass Index (kg/m^2)	21.89 ± 2.25	22.10 ± 1.25	0.201

PLA: Placebo; GF: Ganesh Fit

Overall, there was no significant difference in VO2max between the two groups (p>0.05) as shown in Table 2. Furthermore, in Table 3, the heart rate results of both groups during the two matches showed the intensity of the match produced during the match lasting 2x20 minutes without alternation. There was no significant difference between the PLA and GF groups in the first and second matches (p>0.05).

Table 2. Physical Fitness of PLA and GF Groups

Variable	PLA (n=8)	GF (n=8)	P value
VO_2max (ml/kg/min)	44,77 ± 2,03	46,54 ± 2,27	0.594

PLA: Placebo; GF: Ganesh Fit

Table 3. Heart Rate of PLA and GF Groups in Two Matches

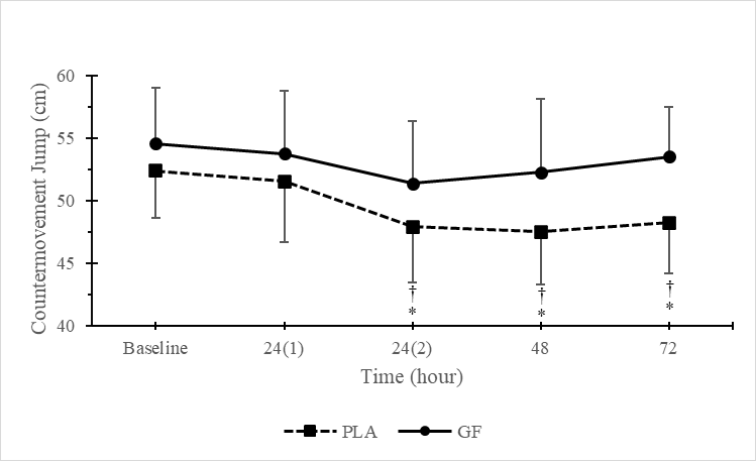
Variable	PLA (n=8)	GF (n=8)	Match day	P value
Heart rate (beat/min)	167 ± 4	168 ± 3	1	0.719
	168 ± 3	169 ± 3	2	0.678

PLA: Placebo; GF: Ganesh Fit

As illustrated in Figure 2, the initial CMJ performance and at 24 h (1) after the first match exhibited no discernible distinctions between the groups (PLA 52.38 ± 3.74 vs. GF 54.56 ± 4.44 cm and PLA 51.56 ± 4.91 vs. GF 53.75 ± 5.05 cm, respectively; p>0.05). Nevertheless, a notable performance decline was observed at 24 h (2) and 48 h after the second match in the PLA group (47.94 ± 4.43 to 47.50 ± 4.17 cm).

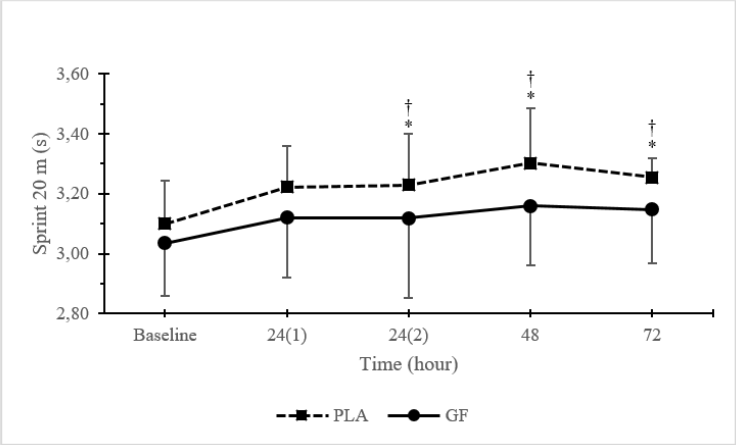
Then, the CMJ value height started to increase 72 h after the second match to 48.25 ± 4.10 cm. There was a significant difference at 24 h (2), 48 h, and 72 h after the second match in the PLA group compared to baseline (47.94 ± 4.43; 47.50 ± 4.17; and 48.25 ± 4.10 cm, respectively; p<0.05). In contrast, the GF group showed a decrease in CMJ height only at 24 h (1) after the first match (53.75 ± 5.05 cm) and 24 h (2) after the second match (51.38 ± 4.99 cm) and started to increase at 48 h and 72 h after the second match with values of 52.25 ± 5.85 cm and 53.50 ± 3.96 cm, respectively. No significant performance differences were observed at 24 h (1) after the first match, 24 h (2) after the second match, 48 h after the second match, and 72 h after the second match (53.75 ± 5.05; 51.38 ± 4.99; 52.25 ± 5.85; and 53.50 ± 3.96 cm, respectively; p>0.05) compared to baseline at GF group. Furthermore, noteworthy distinctions between the two groups emerged at varying time points, i.e., 24 h (2), 48 h, and 72 h after the second match (PLA 47.94 ± 4.43 vs. GF 51.38 ± 4.99; PLA 47.50 ± 4.17 vs. GF 52.25 ± 5.85; and PLA 48.25 ± 4.10 vs. GF 53.50 ± 3.96, respectively; p<0.05). These changes in value were then calculated as percentages. At 24 h (1) after the first match, the decrease in CMJ values in both the PLA and the GF groups (1.58% vs. 1.51%) against the baseline was not significantly different (p>0.05). At 24 h (2) after the second match, the decrease in CMJ results of the PLA group was significantly larger than that of the GF group (9.26% vs. 6.20%; p<0.05) from baseline. The CMJ values of the GF group started returning to baseline values at 48 h and 72 h after the second day of the match, while the CMJ values of the PLA group decreased by 10.26% up to 48 hours after the second day of the match.

Figure 2. The effect of supplementation on countermovement jump.



*Indicates the statistical difference between PLA and GF groups p<0.05. † presents statistical difference compared to baseline in the same groups p<0.05.0: baseline before the first match starts. 24 h (1): 24 hours after the first match. 24 h (2): 24 hours after the second match. 48 h: 48 hours after the second match. 72 h: 72 hours after the second match.

Figure 3. The effect of supplementation on sprint.



*Indicates the statistical difference between PLA and GF groups p<0.05. † presents statistical difference compared to baseline in the same groups p<0.05.0: baseline before the first match starts. 24 h (1): 24 hours after the first match. 24 h (2): 24 hours after the second match. 48 h: 48 hours after the second match. 72 h: 72 hours after the second match.

As depicted in Figure 3, the initial sprint performance and at 24 h (1) after the first match exhibited no discernible distinctions between the groups (PLA 3.10 ± 0.18 vs. GF 3.04 ± 0.14 s and PLA 3.22 ± 0.27 vs. GF 3.12 ± 0.14 s, respectively; p>0.05). There was a significant difference in sprint time at 24 h (2), 48 h, and 72 h after the second match in the PLA group compared to the baseline (3.23 ± 0.20; 3.30 ± 0.20; and 3.25 ± 0.18 s, respectively; p<0.05). In contrast, the GF group showed an insignificant decrease in sprint time at all points, i.e., 24 h (1) after the first match, 24 h (2), 48 h, and 72 h after the second match (3.12 ± 0.14; 3.12 ± 0.17; 3.16 ± 0.18; and 3.15 ± 0.06 s, respectively; p>0.05) compared to the baseline. In addition, important differences in sprint time between the two groups emerged at different time points, namely 24 h (2), 48 h, and 72 h after the second match (PLA 3.23 ± 0.20 vs. GF 3.12 ± 0.14; PLA 3.30 ± 0.20 vs. GF 3.16 ± 0.18; and PLA 3.25 ± 0.18 vs. GF 3.15 ± 0.06 s, respectively; p<0.05). The trend changes in the percentage conversion of sprint time against the baseline was similar to the CMJ result. The percentage decrease between the PLA and GF groups was not significantly different (4% vs. 2.74%; p>0.05) 24 h (1) after the first match. In contrast, at 24 h (2) after the second match, the percentage decrease between the PLA and GF groups was significantly different (3.8% vs. 2.68%; p<0.05). Moreover, at 48 h and 72 h after the second match, the percentage decrease in sprint time of the PLA group was significantly larger than the GF group (6.13% vs. 3.92%; p<0.05) and (4.73% vs. 3.55%; p<0.05) baseline, respectively.

Discussion

Futsal involves an intense game and congested matches. Fast recovery is crucial for futsal players so that they can perform at their best during the match. Curcumin and piperine could be an alternative strategy to optimize recovery for futsal player. The aim of this study was to investigate the effects of GF supplements on futsal player performance after a tight schedule of futsal matches with a short recovery time. To the authors' knowledge, this study is the first study to evaluate the chronic effects of curcumin and piperine supplements on the performance of futsal players undergoing two consecutive matches.

Several studies have reported that physiological measures of VO2max of semi-pro and professional futsal players were in the range of 55.2-71.5 ml/kg/min (Álvarez et al., 2009; Barbero et al. 2008; Naser et al., 2017;). In futsal matches, it was shown that high VO2max values appeared to be important for athletes at the professional level (Álvarez et al., 2009), indicating the importance of aerobic capacity in futsal. In our study, the VO2max was in an overall range of 42-50 ml/kg/min. The difference in the result of VO2max between the current and previous studies may be due to the different levels of the futsal players and different assessments used. The data indicates that amateur futsal players have lower fitness levels than professional players. We found that the VO2max levels of the GF and PLA groups were not significantly different ($p>0.05$), suggesting that the players had similar levels of fitness. The acceleration of the recovery process from high-intensity activities will be achieved when high aerobic levels are present (Spyrou et al., 2020). Besides, a longer recovery period between matches may provide sufficient time for players to recover and prevent the accumulation of fatigue, thereby reducing the risk of injury (Bengtsson et al., 2013).

The heart rate results show the internal load during the match for the players. In this study, both the PLA and the GF produced a high average heart rate ranging from 162-175 beats per minute (bpm), equivalent to 81-87% HRmax in both groups during 'time on the court'. Similar to our results, Yiannaki et al. (2020) and Barbero-Alvarez et al. (2008)reported average heart rates of 165 bpm and close to 174 bpm in futsal players, respectively. According to Keating (2022), activities that evoke HRmax values >80% are considered as 'very vigorous' activities. Based on this, the futsal players were on a high-intensity nature while 'on the pitch'. Thus, a high fitness level is required (Beato et al., 2017; Castagna et al., 2009). Since no significant heart rate difference was observed between the groups during two consecutive matches, the aerobic capacity and match load of both groups were considered similar. The resulting high mean heart rate during a match is due to rapid eccentric movements followed by concentric muscle actions, such as sprinting, jumping, change of direction, acceleration, and deceleration (Spyrou et al., 2020). Futsal players perform 26 times sprints/match on average (Caetano et al., 2015). Our results demonstrate that futsal is a high-intensity sport, which requires a good recovery strategy for players to perform optimally. The differences in match activity load (e.g., playing positions, varying playing durations) and individual fitness (e.g., aerobic and anaerobic capacities) will influence a player's recovery (Nedelec et al., 2014). Futsal also requires the development of physical abilities, techniques, tactics, and strategies. In some matches, coaches avoid player rotation because of the pressure to win, which is a common problem. As a result, the players experience fatigue, resulting in a higher potential for injury. It can be suggested that increased player availability may lead to a greater likelihood of rotating players, either to manage fatigue or for tactical purposes, which could positively influence the team's success (Calleja-González et al., 2023). In addition, a recovery strategy is essential to minimize the risk of injury.

Data on CMJ at various time points provide insights into the potential impact of supplementation on lower-limb explosiveness. CMJ and sprint measurements just before the match (0 h) ensured that the PLA and the GF groups started the study with comparable levels of performance, establishing a strong baseline for subsequent analysis. Players were not considered to optimally recover if there was a decrease in sprint time and jump height (Doeven et al., 2018). The trend of decreasing values in sprint time and jump height can be seen at 24 h (1), 24 h (2), 48 h, and 72 h in both groups compared to baseline. This immediate decrement aligns with the anticipated post-exertion phase characterized by muscular fatigue and potential neuromuscular impairments (Hernández-Davo et al., 2022).Our observations are also in line with previous studies, showing that athletes who experience inadequate recovery generally have impaired CMJ performance (Gescheit et al., 2015). In contrast, athletes with an adequate recovery tend to exhibit the capability to maintain their CMJ performance at the same interval after the competi-

tion (Davies et al., 2018; Delecroix et al., 2017). This study aligns with previous investigations that indicated a decrease in performance (CMJ) 24 h after the second match on consecutive intense matches (Hernández-Davo et al., 2022; Moreno-Perez et al., 2020). Interestingly, the GF group showed a relatively smaller decrease in CMJ performance compared to the PLA group at 24 h (2) after the second-day match, 48 h, and 72 h ($p<0.05$), suggesting that curcumin and piperine supplementation could potentially reduce post-exercise performance decrements. On the other hand, in the PLA group, the inadequate recovery regimen led to the inhibition of the full energy reserves recovery and the repair of micro-lesions in muscle tissue (Żebrowska et al., 2020). The observed difference in sprint time and CMJ height between the two groups implies a plausible ergogenic influence of supplementation, facilitating the maintenance of CMJ performance despite consecutive matches in the GF group. This result indicates that curcumin and piperine supplementation may contribute to accelerating the recovery process, potentially influencing lower limb explosiveness and strength. Our findings have similarities with previous studies reporting that athletes receiving nutritional interventions tend to show a faster recovery trajectory, ranging from 24 h to 72 h after a rigorous competitive match (Faria et al., 2020; Mallard et al., 2021).

Sprint performance measurement at different time points also provides insights into the potential impact of supplementation on lower-limb explosiveness. A trend of decreasing sprint time similar to CMJ can be observed at 24 h (1), 24 h (2), 48 h, and 72 h in both groups compared to baseline. Both groups presented sprint results that started returning closer to baseline values 72 h after the second day of the match. Athletes who have adequate recovery usually show the ability to maintain their sprint performance at the same interval after the competition (Moreno-Perez et al., 2020; Trecroci et al., 2021). This study is consistent with previous reports that show a decrease in sprint performance 24 h after the second match, following consecutive intense matches (Jones et al., 2014; Trecroci et al., 2021). In addition, athletes without an adequate recovery process tend to experience a decrease in sprint performance (Jones et al., 2014).GF may act on several different cytokine-mediated inflammatory pathways to support muscle cell integrity (Nicol et al., 2015), leading to better sprint time performance outcomes than placebo.

Futsal matches are characterized by intermittent high-intensity and tight match schedules, emphasizing a fast recovery process to ensure that players can perform successfully. The sprint time and CMJ height results from this study indicate that the effects of curcumin and piperine supplementation can maintain the performance of futsal players when compared to placebo. Intense exercise produces oxidative stress, which can cause muscle damage and impair performance. The antioxidant abilities of curcumin and piperine counteract the harmful effects of free radicals, which help maintain muscle integrity (Jakubczyk et al., 2020) and improve CMJ and sprint performance. Another important mechanism is their potential to minimize muscle damage and support the repair processes (Ayubi et al., 2023). Curcumin and piperine work synergistically to help reduce micro-lesions and damage caused by futsal matches that require movements such as sprints, jumps, change of direction, accelerations, and deceleration (Álvarez et al., 2009; Spyrou et al., 2020). Curcumin, a bioactive compound derived from turmeric, and piperine, an active component of black pepper, have anti-inflammatory and antioxidant properties that may positively affect muscle function and recovery (Ayubi et al., 2023). By promoting muscle tissue repair and regeneration, these compounds could accelerate recovery and improve sprint and CMJ performance. Intense consecutive futsal matches can induce inflammatory responses that contribute to muscle fatigue and soreness, subsequently affecting CMJ performance (Delecroix et al., 2017). Curcumin has been shown to inhibit inflammatory pathways by targeting molecules such as NF-κB and COX-2 (Faria et al., 2020; Tanabe et al., 2019). By attenuating excessive inflammation, curcumin could aid in preserving muscle function, potentially enhancing sprint and CMJ performance. As shown in this study, the GF group had improved recovery compared to the PLA group, highlighting the potential of GF on players' performance following a vigorous schedule.

Despite the attempt to design and implement a study with a strong methodology, certain limitations are inevitable. Ideally, a cross-over design would have been preferred, but it was considered inappropriate due to the potential adaptation of training effects during the cross-over phase. The cross-over design required a long washout period, which lengthened the duration of the study by several months. In addition, as this study is the first investigation of the effects of curcumin and piperine supplements on muscle function, the optimal dose to attenuate muscle damage and improve performance efficiently remains unknown. It would be beneficial to compare the effects of different doses of the combined supplement

on muscle function. This study did not include muscle damage biomarker measurements, and as such, limiting our understanding towards the mechanisms for the observed trends. To gain a comprehensive understanding, future research might explore larger participant cohorts, a broader range of performance indicators, and mechanistic insights through biochemical assays. The effectiveness of these strategies when used in combination has not been explored further. Several combinations of recovery strategies can be used to optimize the recovery process further. This supplementation strategy could be an option to maintain players' performance despite the competition schedule being an important factor in the players' recovery. Further research is needed to explore the implications of this supplementation strategy in other sports.

Conclusions

Our study provides evidence to support the use of curcumin and piperine supplementation for 13 days at a dose of 200 mg curcumin and 10 mg piperine to positively impact CMJ performance and sprint times after intense and consecutive futsal matches. These findings suggest that the combination of curcumin and piperine contributes to recovery improvement and maintenance of performance in futsal athletes with rigorous competition schedules.

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Authors' and translators' details:

Agung Dwi Juniarsyah	agung.d@itb.ac.id	Author
Tommy Apriantono	tommy@itb.ac.id	Author
Neng Fisheri Kurniati	nfkurniati@itb.ac.id	Author
Bagus Winata	bagusofficial10@gmail.com	Author
Muhamad Fahmi Hasan	fahmi.hasan@itb.ac.id	Author
I Ketut Adnyana	adnyana@itb.ac.id	Author
Yudhi Teguh Pambudi	yudhi.teguh@unsoed.ac.id	Author