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Paper review *Pregledni rad*

The Potential Application of Neck-Head Cooling During Matches as a Thermoregulatory Strategy to Optimize Badminton Athletes' Performance: A Scoping Review

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Abstract: *As a high-intensity intermittent sport, badminton requires rapid physiological recovery strategies between intervals to prevent performance decline due to accumulated thermal stress. Practical cooling methods that can be applied on the court are crucial to maintaining athletes' consistency in competition. The purpose of this study was to analyze the potential application of the neck-head cooling method as a thermoregulation strategy to optimize the recovery and performance of badminton athletes. A scoping review design was used in this study with guidelines adopting PRISMA-ScR. A search of articles from the Scopus and PubMed databases yielded a total of 663 articles, of which 11 were eligible and relevant for analysis. The review focused on the impact of the intervention on the participants' physiological parameters, physical performance, and perceptual performance. The literature synthesis showed that the application of neck-head cooling facilitated recovery, as indicated by an increase in time to exhaustion and a faster decrease in heart rate. This effectiveness was predominantly mediated by perceptual mechanisms, through a decrease in RPE and an increase in thermal comfort, rather than a significant physiological decrease in core body temperature. The neck-head cooling method is recommended as an efficient and practical psychophysiological strategy for badminton athletes to delay systemic fatigue and maintain peak performance stability, even though it does not directly contribute to improving physical and technical performance.*
Keywords: *Thermoregulation, neck cooling, head cooling, cooling strategy, badminton performance*

Introduction

Badminton can be categorized as a high-intensity intermittent sport that requires a combination of aerobic endurance, anaerobic endurance, and high reaction speed during a match (Alvarez-Dacal et al., 2025; Xia et al., 2025; Yaprak, 2020). In high-level badminton matches, the duration of the match can last between 30 and 60 minutes (or even longer) (bahkan lebih) (Iizuka et al., 2020; Phomsoupha et al., 2019). Badminton is also often played indoors in high humidity environments (Xie et al., 2021), especially when played in spring (62.95%), summer (64.45%), and highest in autumn (72.33%) (Liu et al., 2024). These environmental conditions create thermoregulatory challenges, where body heat accumulation (hyperthermia) can occur rapidly due to the explosive intensity of the movements (Bartman et al., 2022; Bongers et al., 2021).

Increases in core body temperature during physical activity in hot environments are known to have a direct impact on the declining performance of athletes (Alhadad et al., 2019; Naito et al., 2024; van Delden et al., 2019). These physiological consequences contribute to the onset of fatigue, both peripheral fatigue in the muscles and central fatigue in the central nervous system (Lloyd et al., 2015; Nybo, 2012; Périard, 2016). This thermal fatigue (heat strain) not only reduces physical capacity, such as the ability to run fast repeatedly, but also degrades cognitive functions such as awareness and decision-making (Maric et al., 2015; Schmit et al., 2016).

Currently, cooling strategies are the primary intervention for mitigating the negative effects of heat (Alhadad et al., 2019; Bongers et al., 2015; Gutiérrez-Arroyo et al., 2025). However, conventional methods such as cold water immersion (CWI) are generally performed before or after the game due to time and logistical constraints (Arampatzis et al., 2020; Bouchiba et al., 2022; Pereira et al., 2025; Seco-Calvo et al., 2020). On the other hand, in-game cooling strategies (per-cooling) using neck or head cooling methods offer a more practical solution (Cao et al., 2022; S. M. Chalmers, 2017; Schranner et al., 2017). The neck and head areas have high thermal sensitivity and are close to the thermoregulatory center in the brain, so intervention in these areas is hypothesized to provide a significant perceptual cooling effect (Tyler & Sunderland, 2011). Additionally, this method is considered to provide a signal that delays

central fatigue even without a drastic decrease in core body temperature, making it an effective and efficient strategy to apply during interval breaks (Cao et al., 2022; Stevens et al., 2016).

Although this theoretical basis is strong, specific literature on the application of neck or head cooling methods during competition in the badminton athlete population is still limited compared to other racket sports, such as tennis (Schranner et al., 2017). Therefore, this scoping review study aims to map the literature evidence on the potential, mechanisms, and effectiveness of neck or head cooling methods during competition as a thermoregulation strategy to optimize the performance of badminton athletes and provide appropriate recommendations for future research.

Methods

Study Design

This study is a scoping review, which aims to summarize the types of evidence available in a specific dimension; summarize existing evidence; analyze gaps in the manuscript; and provide recommendations for future research (Rodger et al., 2024). This study has a general objective of systematically reviewing scoping reviews on the application of neck and head cooling methods as an acute recovery and performance optimization strategy for athletes, with a specific focus on the characteristics of badminton as a high-intensity intermittent sport.

Eligibility Criteria

The articles used were original articles published from 2015 to 2025 (as of August 2025). The databases used to search for manuscripts were Scopus and PubMed. The articles to be reviewed in this literature study were determined based on inclusion and exclusion criteria according to the PICOS (Population, Intervention, Comparison, Outcome, Study Design) principle, with the following conditions:

Table 1. *Eligibility Criteria Based on PICOS Principles and Accessibility & Language*

Category	Inclusion Criteria	Exclusion Criteria
Population	Competitive athletes or physically active healthy individuals. Junior or adult athletes (18-40 years old). Athletes in intermittent and endurance sports.	Populations with a history of cardiovascular disease. Post-injury or rehabilitation phase athletes and athletes with disabilities.
Intervention	External cooling methods, applied specifically to the head, neck, or face, or in combination with internal cooling. Techniques: ice towels, cooling collars, headbands, water sprays, and similar methods. Timing: administered during activity or breaks in play (mid-cooling/mid cooling/per cooling or combined with pre/post cooling) or rest intervals.	Internal cooling method only (ice slurry) without external cooling. Pharmacological intervention (supplements/medication).
Comparison	Control group without cooling treatment (no cooling/passive rest). Comparison with other alternative cooling methods.	Descriptive study without a control group or without a comparison condition.
Outcomes	Report at least one of the following parameters: 1. Performance: physical, cognitive, or technical; 2. Physiological: heart rate, body temperature (skin/core); 3. Perceptual: RPE, thermal sensation, thermal comfort.	Engineering articles without human testing.
Study Design	Experimental studies (RCT, crossover design, quasi-experimental).	Literature studies, case reports, editorials, or expert opinions. Conference abstracts with incomplete data.
Accessibility and Language	Full text articles available (open access or subscribed by institution). English languages.	Paid articles (closed access/paywall). Languages other than English.

Procedures

The research process began with observational studies and document reviews to formulate the topic, urgency of the research, and research title, followed by the determination of research questions to maintain the focus of the discussion. Literature searches were conducted on the Scopus and Pubmed databases using keyword searches with the Boolean method. In the Scopus database, the following search strategy was used: ("ice" OR "cooling" OR "cooling strategy" OR "neck cooling" OR "head cooling") AND ("thermoregulation" OR "thermoregulatory" OR "recovery" OR "fatigue") AND ("exercise" OR "training" OR "performance" OR "match" OR "matches" OR "sport" OR "sports") AND ("active person" OR "actively" OR "healthy person" OR "healthy" OR "athlete" OR "athletes"). In the PubMed database, the following search strategy was used: (ice OR cooling OR cooling strategy OR neck cooling OR head cooling) AND

(thermoregulation OR thermoregulatory OR recovery OR fatigue) AND (exercise OR training OR performance OR match OR matches OR sport OR sports) AND (healthy person OR healthy OR active person OR actively OR athlete OR athletes). This search found a total of 663 articles (495 from Scopus and 168 from PubMed). The initial screening process reviewed the titles and abstracts of the articles, resulting in 199 articles. After checking for duplicate articles from the two databases, 182 articles remained. Further screening was conducted by looking at the criteria eligible for review, in accordance with the criteria in Table 1. The results of the final analysis and agreement of the author team showed that 11 articles were deemed eligible for use. The writing of this scoping review article refers to the PRISMA-ScR (Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Review) guidelines. Below is a PRISMA-ScR analysis image conducted in this scoping review study:

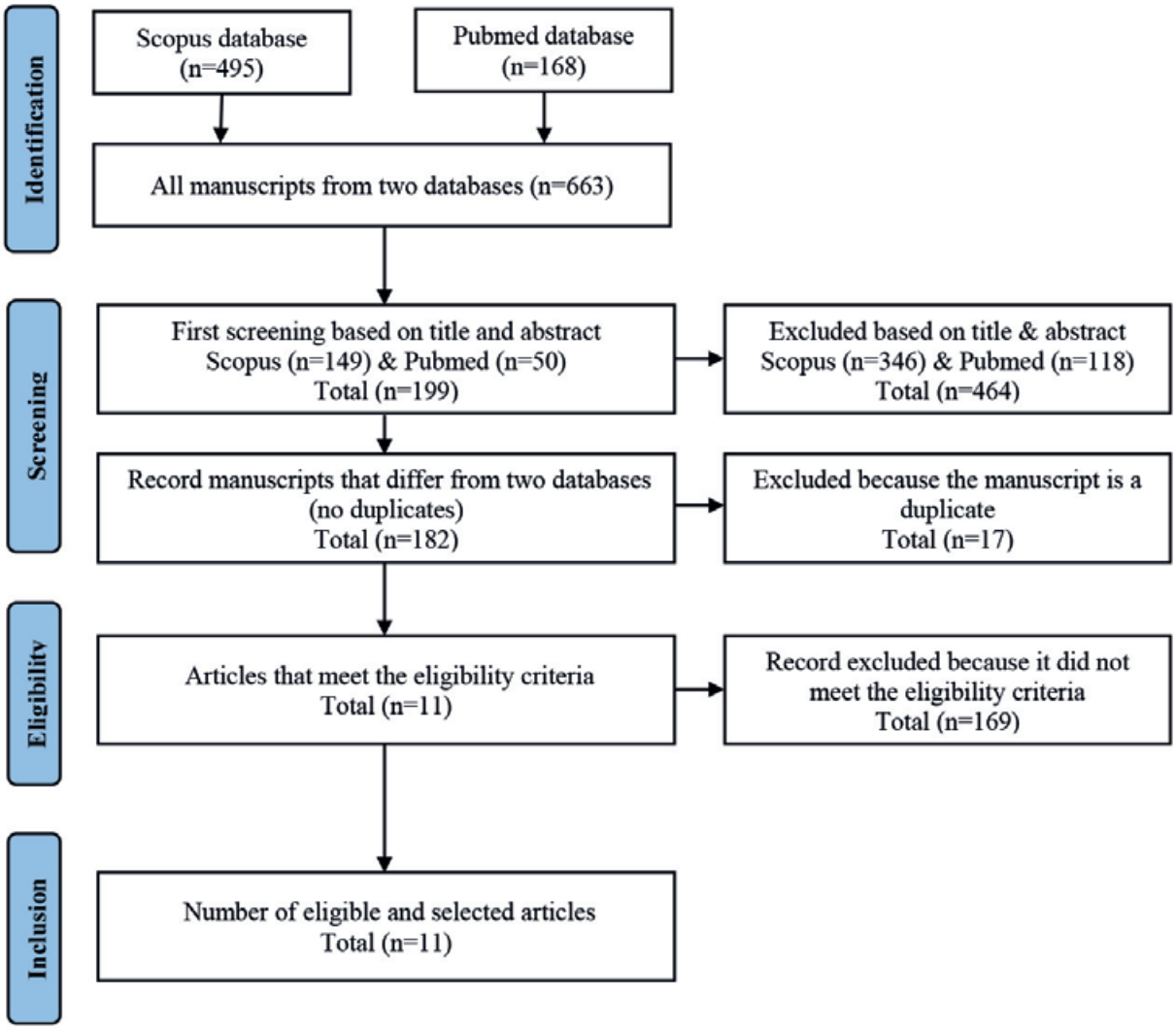


Figure 1. *PRISMA Flowchart of article selection process*

Results

From 663 articles obtained from two main databases, Scopus and Pubmed, 11 articles were selected that were feasible and relevant to the topic and objectives of this scoping review. The results of the analysis of these 11 articles are presented in the table below.

Table 2. *Articles that fulfil the eligibility criteria and were analysed*

No	Authors	Method and Study Design	Participant	Intervention	Comparison	Performance findings (physical/skill)	Physiological/perceptual findings
1	(Desai & Bottoms, 2017)	Experimental Design. Conducted in match simulations.	Table Tennis Athletes (National Level)	Neck cooling applied during point/set breaks..	No Cooling (Control)	Improved stroke accuracy (skill) and motoric reaction..	Significant improvement in thermal comfort.
2	(Sunderland et al., 2015)	True Experimental (Laboratory). Randomized Crossover Design in a climate chamber (controlled heat room).	Male athletes actively involved in team sports for at least 3–4 hours per week	Neck Cooling applied during rest intervals between sprints.	No (Kontrol)	Maintained peak power and speed in the final repetition.	Decreased RPE (perceived exertion); athletes felt the exercise was easier.
3	(Yoshihara et al., 2024)	Experimental Crossover. Intermittent treadmill exercise protocol	Twelve Female Tennis Players	Cooling Break (10 menit). Cold Water Immersion (CWI), ice towel, cooling vest.	Passive Rest (Without cooling) and Control	Potential as a strategy to reduce Exertional Heat Illness (EHI) that impacts physical performance	Cooling strategies during the 10-minute break were able to lower rectal temperature and heart rate.
4	(Desroches et al., 2024)	Randomized Crossover Trial. Submaximal running protocol + time trial.	Ten endurance male athletes.	Omius Headband (evaporative cooling on the forehead).	Regular headband (Sham).	No significant difference in running time, but there were subjective benefits.	Increased local cooling sensation on the head (Local Thermal Sensation).
5	(Walters et al., 2017)	Experimental Crossover. Maximum performance test (3 tests).	Twenty two recreationally active male subjects.	Head cooling was administered intermittently for 7 minutes.	Placebo (no cooling) consisted of the same cap but without cold fluid circulation.	There was a difference in peak power output between the cooling and placebo groups.	The main mechanism for performance improvement was a reduction in heat perception.
6	(Jackson et al., 2015)	Laboratory Experiment. Randomized Crossover Design. Measuring cognitive and autonomic responses.	Twelve Healthy Volunteers	Selective Head-Neck Cooling (Focus on specific areas).	Control	Maintaining attention (vigilance) and executive function. Due to stable cognitive test scores.	Significant decrease in tympanic temperature. Stable heart rate, blood pressure, and oxygen saturation within normal ranges.
7	(Miyazawa et al., 2021)	Constant intensity exercise (40 minutes of ergometric cycle exercise at 65% of peak HR) in a hot environment.	Ten active and healthy men	Face Cooling using soft-gel packs applied intermittently to the forehead, eyes, and cheeks. Intervention variations: FC2 (Cooling every 2 minutes at 0ºC); FC 4 (Cooling every 4 minutes at 0ºC); FC2-20 (Cooling every 2 minutes at 20°C)	Without facial cooling	Subjects receiving the intervention felt lighter when performing the same workload.	Significant reduction in RPE; Temperature continued to rise (perception dissociation). Cooling with faster intervals (every 2 minutes) and colder temperatures (0°C) provided the greatest reduction in RPE.
8	(Ishizuka et al., 2025)	Randomized Crossover Trial (RCT). Ergometer cycle exercise for 20 minutes at 50% HRR intensity and a 15-minute rest period in a hot room.	Fourteen healthy adult males.	Neck Cooling using a special cooler containing 1200 grams of ice worn during the 20-minute exercise and 15-minute rest period.	Control	Not effective in preventing an increase in body temperature and feelings of fatigue during exercise.	Proves that the effect is purely perceptual, not a decrease in temperature. Although there was no significant difference in RPE compared to the control group.

9	(Mazalan et al., 2021)	Randomized Crossover Design. Running on a treadmill for 60 minutes (divided into two 30-minute sessions with a 10-minute break between sessions) in a hot climate chamber. Participants performed working memory tests before exercise, at the midpoint (30 minutes), and after exercise (60 minutes) to measure cognitive function.	Ten male endurance athletes who were not accustomed to extreme heat.	Pre-cooling (head) before exercise began using a cooling cap (temperature 0ºC) worn for 15 minutes immediately before starting to run.	Control (using the same cap but not cooled (temperature 22ºC/room temperature).	No significant differences were found in specific cognitive tests.	This indicates that timing (before vs. during) is highly influential. Forehead temperature decreased significantly immediately after the intervention but not during exercise.
10	(De Nardi et al., 2024)	Randomized Controlbalanceed Crossover Design. High-speed Time to Exhaustion test.	Twelve trained male middle-distance runners	Cryo-facial mask (ice mask with a device called XºCRYO) worn during the 3-minute break between warm-up and core test.	Control (using the same mask, but with the machine turned off/no cold air flow)	Significant increase in Time to Exhaustion (TTE); the Cooling group was able to run longer than the control group.	Decrease in facial skin temperature (Tskin-face) correlated with comfort. HR and RPE showed no significant differences during TTE.
11	(Pariyavuth et al., 2023)	Randomized counterbalanced repeated measures design (each athlete underwent 4 random interventions with a 7-day interval). Match simulation: 3 rounds x 2 minutes wearing full uniform.	Ten experienced male Taekwondo athletes.	Cold water immersion (CWI) at 15ºC for 5 minutes; consumption of ice slurry (ICE) at -1ºC at a dose of 7.5g/kg body weight.	Passive sitting rest (CON); thermoneutral water immersion (TWI) at a neutral temperature (35ºC) for 5 minutes.	No significant differences in match performance, both in psychomotor and neuromuscular skills.	ICE was most effective in rapidly lowering core temperature at 30-45 minutes into recovery. CWI could not significantly lower core temperature. HR CWI showed consistently lower values than the control group during recovery. This indicates that if the rest duration is too short, the cooling effect may be minimal.

Discussion

The purpose of this study is to review the literature on the potential effectiveness of neck and head cooling methods as a practical thermoregulation strategy for badminton athletes. From the results of the data synthesis that has been carried out, this discussion has four sub-topics: effects on acute recovery, optimization of performance in competition, thermal regulation mechanisms, and potential and limitations of application in the field.

The Potential of Neck and Head Cooling Methods During Badminton Match Breaks in Accelerating Acute Recovery

Badminton is a high-intensity intermittent sport (Phomsoupha et al., 2019), and the ability to recover physiological conditions during short interval breaks (60–120 seconds) is a crucial determinant of performance sustainability, both during point intervals and set changes. Based on a literature review, local cooling methods applied to the head and neck areas show significant potential as an acute recovery modality (Sunderland et al., 2015; Yoshihara et al., 2024). Findings indicate that short-duration cooling interventions on the face, head, or neck during match breaks are sufficient to trigger beneficial physiological responses (De Nardi et al., 2024).

This recovery mechanism does not work through a drastic decrease in muscle temperature, but rather through modulation of the nervous system. Cold stimulation of thermal receptors in the neck and face is known to innervate the trigeminal nerve, which then triggers an increase in parasympathetic activity (Johnson et al., 2017; Louis et al., 2015). This vagal response contributes to a faster reduction in recovery heart rate frequency compared to passive rest without cooling (Abbiss et al., 2021; Coote, 2010). Other studies have also found that applying cooling methods to the neck or face stimulates skin thermal receptors that innervate the trigeminal nerve (Cao et al., 2022; Miyazawa et al., 2021). This stimulation triggers a parasympathetic response that helps lower heart rate and reduce the perception of shortness of breath more quickly than passive rest (Canikli Adıgüzel et al., 2023; Jungmann et al., 2018). This is

particularly crucial in sports with short rest intervals, where methods to accelerate the reduction of body heat sensation hold significant strategic value (Bright et al., 2019).

The Effectiveness of Neck and Head Cooling Methods in Optimizing Badminton Performance

A literature review confirms that neck and head cooling has a positive impact on two main aspects of performance, namely physical capacity and technical skills (Desai & Bottoms, 2017; Sunderland et al., 2015).

In terms of physical capacity, studies have shown that neck cooling can maintain repeated sprint performance in hot conditions (Sunderland et al., 2015). he study found that cooling the neck area during rest intervals can maintain peak power output and running speed in the final phase of training in a hot environment. This is in line with the findings of a study conducted on endurance athletes, which found that the use of cooling devices on the head is practical in conditions of high thermal stress because it helps maintain performance stability (Desroches et al., 2024). The mechanism involved is closely related to a decrease in the rate of perceived exertion (RPE), where athletes feel "not so tired" and are able to maintain high activity intensity (Miyazawa et al., 2021).

In terms of technical and cognitive skills, significant evidence was found in studies conducted on table tennis athletes, where this sport has similar cognitive characteristics to badminton (Desai & Bottoms, 2017). The results of the study showed that athletes who were given neck cooling interventions had an advantage in performing consistent strokes compared to the control group (Desai & Bottoms, 2017). This indicates that cooling the neck area is effective in preventing the decline in fine motor and cognitive functions that usually occurs due to heat stress (Jackson et al., 2015). Other literature also mentions that intermittent cooling of the head area can prolong the time to voluntary exhaustion, allowing athletes to maintain the quality of their strokes for longer during matches (Walters et al., 2017; Yoshihara et al., 2024).

Thermoregulation Mechanisms of Neck-Head Cooling: Physiological vs. Perceptual

Literature analysis shows that the effectiveness of neck-head cooling does not always correlate with a significant decrease in core body temperature (Ishizuka et al., 2025). This is because the relatively small surface area of the neck and head is considered insufficient to rapidly cool the total blood volume, so rectal temperature often does not differ significantly from the control group (Bright et al., 2019; Yoshihara et al., 2024).

Manipulation of thermal perception and thermal comfort is one of the main working mechanisms (Desroches et al., 2024). Cooling in the neck area sends a cool signal to the hypothalamus, which then suppresses the fatigue danger signal from the brain (Cotter & Taylor, 2005; Zhang et al., 2025). This results in the brain allowing the body to maintain high intensity even though the body's physiological temperature is still high (Cao et al., 2022; Sunderland et al., 2015).

Potential and Limitations of Applying Neck and Head Cooling Methods to Badminton Players

The application of neck and head cooling in badminton athletes offers high economic viability. This method, whether in the form of ice packs, ice bags, cooling collars, or headbands, can be practically integrated into interval breaks without violating match rules (S. Chalmers et al., 2019; Desroches et al., 2024). In addition to physical benefits, this intervention also has the potential to restore mental focus disrupted by heat and provide psychological advantages at critical or final points.

However, there are limitations that need to be considered. Several studies report that the application of cooling methods does not have a significant positive effect, indicating that the effectiveness of this method is highly dependent on the duration or timing of the cooling intervention (Mazalan et al., 2021; Pariyavuth et al., 2023). A rest period that is too short does not provide sufficient time for thermal receptors to trigger an optimal recovery response. In addition, the application of this method can also cause the risk of athletes pushing themselves beyond safe limits because they feel cooler than their actual body temperature. Therefore, monitoring vital signs after high-intensity competitions is necessary to prevent heat illness. Furthermore, comfort factors such as water droplets wetting clothing or the field are also technical considerations that need to be anticipated.

Conclusions

Based on the literature review conducted, neck and head cooling strategies have been identified as promising intervention methods in the acute recovery management of athletes in high-intensity intermittent sports, such as bad-

minton. The efficacy of this method is primarily mediated by perceptual mechanisms, through a reduction in RPE and an increase in thermal comfort, although it does not provide an instant increase in core body temperature reduction and neuromuscular power in a short duration. The practical implications of these findings are to advise sports practitioners and coaches to integrate neck and head cooling protocols as an efficient psychophysiological strategy during interval breaks, in order to maintain the consistency of badminton athletes' performance and delay the onset of systemic fatigue.

Considering that current literature is dominated by strictly controlled laboratory protocols, future research is strongly encouraged to improve ecological validity through several specific approaches. Future research is needed with standardized badminton simulation protocols that replicate specific movement patterns (such as lunges, jumping, hitting, and rapid changes of direction) to verify the consistency of the cooling effect on the neuromuscular complexity of this sport. Additionally, research is needed to determine the effectiveness of neck and head cooling in actual match situations, where dynamic environmental conditions and psychological pressure can affect thermoregulatory responses. Furthermore, future research should evaluate the impact of this method on cognitive aspects, particularly the accuracy of tactical decision-making when athletes are fatigued at crucial points in a match.

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