2024, Retos, 59, 857-863

The effectiveness of cold temperature and warm temperature therapy in overcoming badminton athlete fatigue

Eficacia de la terapia de temperatura fría y temperatura templada para superar la fatiga de los atletas de bádminton

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Abstract. This study aims to test and determine the differences in the influence and effectiveness of cold temperature therapy and warm temperature therapy on fatigue in badminton athletes. This research uses a quasi experimental designs research method with a one group time series (pretest one post test) design. In this design, the first observation (pretest) is carried out after that the posttest observation. The treatment group was measured by providing cold temperature therapy and warm temperature therapy for fatigue which will be known to consist of three (3) indicators, namely: (1) Pulse Rate (DN) (2) Rating of Perceive Exertion (RPE) and (3) Blood Lactate Levels (LD). The research sample was taken from the existing population using a purposive sampling method with a total of 20 samples. Data collection is obtained through tests and measurements. The test instruments used to measure fatigue are stop time, questionnaires and Accutrend Lactate. The analysis technique uses the t test "paired sample t test and independent sample t test". The research results show that there is a significant difference between cold temperature therapy and warm temperature therapy on fatigue consisting of pulse rate, Rating of Perceive Exertion and blood lactate with a significance value of <0.05 using the paired t-test, a DN value of 0.049 , the RPE value is 0.003 and the LD value is 0.006. So it can be interpreted that there is a significant influence on the treatment given with cold temperature therapy and warm temperature therapy on the fatigue variable for badminton athletes. Based on the percentage results obtained, it can be said that cold temperature therapy is more effective in reducing DN and LD. Meanwhile, warm temperature therapy is more effective in reducing RPE.
Keywords: therapy, cold, warm, fatigue, badminton

Resumen. Este estudio tiene como objetivo probar y determinar las diferencias en la influencia y la eficacia de la terapia de temperatura fría y la terapia de temperatura caliente sobre la fatiga en los atletas de bádminton. Esta investigación utiliza un método de investigación de diseño cuasi experimental con un diseño de serie temporal de un grupo (pretest un postest). En este diseño, la primera observación (pretest) se lleva a cabo después la observación postest. El grupo de tratamiento se midió proporcionando terapia de temperatura fría y terapia de temperatura cálida para la fatiga, que se sabrá que consta de tres (3) indicadores, a saber: (1) Frecuencia de Pulso (DN) (2) Valoración del Esfuerzo Percibido (RPE) y (3) Niveles de Lactato en Sangre (LD). La muestra de la investigación se tomó de la población existente mediante un método de muestreo intencional con un total de 20 muestras. La recogida de datos se obtiene mediante pruebas y mediciones. Los instrumentos de prueba utilizados para medir la fatiga son el tiempo de parada, los cuestionarios y el Accutrend Lactate. La técnica de análisis utiliza la prueba t "prueba t de muestras emparejadas y prueba t de muestras independientes". Los resultados de la investigación muestran que existe una diferencia significativa entre la terapia con temperatura fría y la terapia con temperatura templada sobre la fatiga consistente en la frecuencia del pulso, la Valoración del Esfuerzo Percibido y el lactato en sangre con un valor de significación <0,05 utilizando la prueba t pareada, un valor de DN de 0,049 , el valor de RPE es de 0,003 y el valor de LD es de 0,006. Por tanto, puede interpretarse que existe una influencia significativa del tratamiento administrado con terapia de temperatura fría y terapia de temperatura templada en la variable fatiga de los deportistas de bádminton. Según los resultados porcentuales obtenidos, puede decirse que la terapia de temperatura fría es más eficaz para reducir la DN y la LD. Por su parte, la terapia con temperatura templada es más eficaz para reducir la EPR.
Palabras clave: terapia, frío, calor, fatiga, bádminton

Fecha recepción: 07-06-24. Fecha de aceptación: 26-07-24
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Introduction

Fatigue recovery is a crucial aspect of badminton athletes' long-term performance and health. The sport is high-intensity, with explosive movements, rapid direction changes and constant concentration, resulting in significant physical and mental fatigue. Proper recovery allows athletes to prevent injury, improve performance, maintain cognitive health, optimize physiological adaptation, and avoid overtraining. Without adequate recovery, athletes risk decreased coordination and concentration and increased risk of injury. Effective recovery strategies include sufficient rest, proper nutrition, hydration, active recovery, physical therapy and stress management. Coaches and support teams should monitor athletes for signs of fatigue and adjust training programs as needed.

By implementing a comprehensive recovery strategy, badminton athletes can consistently and sustainably achieve optimal performance, guaranteeing a long and healthy career. Good recovery improves short-term performance and allows the body to adapt to the training load, improving strength, endurance and technical skills. During the recovery phase, the body performs tissue repair, energy replenishment, and adaptation to training stress, which is critical to an athlete's

development. By understanding and prioritizing fatigue recovery, badminton athletes can maximize their potential and achieve high performance in the long run.

In Indonesia, sports, including badminton, have developed quite well. The development of badminton in Indonesia has reached a very rapid stage of development and has attracted the attention of many people; it is proven that Indonesia's name is immensely respected in badminton, and the fact is undeniable that Indonesia is a badminton giant country related to its success in making achievements in various world-class championships, one of which is the Olympics (Kozin et al., 2023; Luna, Márquez, Rodriguez, Martínez, & Vargas, 2019). Achievement in badminton can be seen from the indicators it gets. Good achievement is supported by good performance, so the decline in performance will undoubtedly be an obstacle to achievement. One of the causes of decreased performance can be fatigue. Fatigue is when a person constantly feels tired, lethargic, or lacks energy; this condition is not the same as feeling sleepy. Iwandana et al. (2022) state that the state of fatigue includes physical and psychological aspects as well as subjective fatigue, which is characterized by decreased physical function, feelings of fatigue, reduced motivation, and reduced work efficiency. The higher the activity, the faster fatigue will arise (Giriwijoyo & Sidik, 2010). The cause of physical fatigue in athletes is due to the accumulation of lactic acid in the muscles; as stated by Dinagsit (Ihsan, Nasrulloh, Nugroho, & Kozina, 2024; Ihsan, Nasrulloh, Nugroho, & Yuniana, 2024), fatigue arises due to the accumulation of lactic acid in the tissue.

A problem for badminton players is that the recovery due to fatigue is prolonged; this is because the recovery process could be better, such as cooling down, where players often cool down carelessly so that the impact on fatigue recovery does not run quickly and optimally. The poor recovery process will impact the quality of the player's physical activity, which will decrease, in addition to badminton match activities, often playing in a row once a day, sometimes even twice a day. With a fast fatigue recovery process, the quality of the game in the next match will be maintained.

With the development of an increasingly modern and complex era, there are currently many outstanding recovery methods in sports development, including cold and warm temperature therapy. Hydrotherapy at reasonably low temperatures compared to very low temperatures can cause relatively positive effects on muscle damage and the recovery phase after eccentric exercise in the arm (Jo et al., 2021). In addition, based on the results of research by Kusuma et al. (2020), it was found that cold-temperature water baths accelerate the recovery process, reduce muscle inflammation, and reduce stress. In addition, there are also research results for warm temperature therapy conducted by Setiawan (2019), which say that greater water temperatures tend to produce more minor lactic acid levels. This suggests that the effect of a more significant temperature in this study of 300 C (warmer water) provides better relaxation. Nurmaulina Hadiyanto (2021) states that foot soak therapy using warm water significantly lowers blood pressure. Based on the abovementioned problems, researchers are interested in applying cold-temperature and warm-temperature therapy models to overcome fatigue in badminton athletes.

Methods

This research uses quasi-experiment designs with a one-group time series design (pretest, one posttest). In this design, the first test (pretest) is carried out, after which treatment is given, and the final test (posttest) is carried out. The treatment group was given cold temperature and warm temperature therapy. Fatigue recovery with three indicators, including measurement of Pulse Rate (DN), Rating of Perceived Exertion (RPE), and Blood Lactate Level (LD), which are known before and after the provision of cold temperature and warm temperature therapy. The population in this study were students of the Sports Science study program who took badminton elective sports courses in semester 3. The research sample will be taken using a purposive sampling technique to determine the sample with specific criteria (Sugiyono, 2018). The criteria for determining the sample in this study are 1) male players, 2) players aged 19-20 years, 3) willing to do research treatment as long as it has been determined, and 4) have experience competing in badminton at the provincial level. From these criteria, the research sample amounted to 20 and was divided into two groups.

The treatment in this study was applied cold temperature therapy and warm temperature. Cold temperature therapy is soaking in cold water at 10 - 15 0C for 12 minutes in a sitting position, specializing in soaking the lower limbs. At the same time, warm temperature therapy soaks in warm water at 37 - 38 0C for 12 minutes in a sitting position specialized in lower limb immersion. The data collection technique used is the survey method of test and measurement techniques. Tests and measurements for data collection include measuring lactic acid levels in the blood using a tool called Accutrend Lactate (Lactate Meter). Data analysis techniques in this study used normality tests, homogeneity tests, and hypothesis testing. The normality test calculation aims to determine whether the sample is from a normally distributed population. The homogeneity test helps test the similarity of several samples and whether the sample variants taken from the population are uniform. After calculating the normality and homogeneity tests, hypothesis testing is carried out using the t-test "paired sample t-test and independent sample t-test." Maksum's (2016) data analysis techniques utilize the t-test with a significance of 5%.

Results

Based on the results of testing the respondents' test data with the frequency test, it is known that the frequency data is calculated based on average cold temperature therapy data and warm temperature therapy to determine the category (minimum, maximum, and mean). The average cold temperature therapy data and warm temperature therapy have been calculated with statistical calculations using the help of SPSS 22.0 for Windows. The results of data processing with the frequency test that researchers have carried out can be seen in the following table:

a. Description of Pulse Rate (DN) Data

Table 1.
Statistical Description of DN Data

Group	N	Mean	Std. Deviation	Range	Min	Max	Sum
Pre Cold	10	123.6000	7.16783	24.00	112.00	136.00	1236.00
Post Cold	10	72.6000	10.15655	34.00	60.00	94.00	726.00
Pre Warm	10	126.0000	6.03692	20.00	116.00	136.00	1260.00
Post Warm	10	81.2000	14.85336	40.00	64.00	104.00	812.00

From the table above, it can be explained that the DN cold temperature therapy pretest data with a sample size of 10 obtained a mean value of 123.60, Std. Deviation 7.16, range 24.00, minimum value 112.00, maximum value 136.00, and total value (sum) 1236.00. DN cold temperature therapy posttest data with a sample size of 10 obtained a mean value of 72.60, Std. Deviation 10.15, range 34.00, minimum value 60.00, maximum value 94.00, and total value (sum) 726.00. DN warm temperature therapy pretest data with a sample size of 10 obtained a mean value of 126.00, Std. Deviation 6.03, range 20.00, minimum value 116.00, maximum value 136.00, and total value (sum) 1260.00. DN warm temperature therapy posttest data with a sample size of 10 obtained a mean value of 81.20, Std. Deviation 14.85, range 40.00, minimum value 64.00, maximum value 104.00, and total value (sum) 812.00.

b. Description of Rating of Perceived Exertion Data (RPE)

Table 2.
Deskripsi Statistik Data RPE

Group	N	Mean	Std. Deviation	Range	Min	Max	Sum
Pre Cold	10	15.8000	1.68655	6.00	13.00	19.00	158.00
Post Cold	10	9.6000	1.07497	3.00	8.00	11.00	96.00
Pre Warm	10	17.0000	1.63299	4.00	15.00	19.00	170.00
Post Warm	10	10.2000	1.31656	4.00	8.00	12.00	102.00

From the table above, it can be explained that the pretest data of RPE cold temperature therapy with a sample size of 10 obtained a mean value of 15.80, Std. Deviation 1.68, value range (range) 6.00, minimum value 13.00, maximum value 19.00, and total value (sum) 158.00. RPE cold temperature therapy posttest data with a sample size of 10 obtained a mean value of 9.60, Std. Deviation 1.07, range 3.00, minimum value 8.00, maximum value 11.00, and total value (sum) 96.00. RPE warm temperature therapy pretest data with a sample size of 10 obtained a mean value of 17.00, Std. Deviation 1.63, range 4.00, minimum value 15.00, maximum value 19.00, and total value (sum) 170.00. RPE warm temperature therapy posttest data with a sample size of 10 obtained a mean value of 10.20, Std. Deviation 1.31, range 4.00, minimum value 8.00, maximum value 12.00, and total value (sum) 102.00.

c. Blood Lactate Data Description (LD)

Table 3.
Statistical Description of LD Data

Group	N	Mean	Std. Deviation	Range	Min	Max	Sum
Pre Cold	10	12.5000	2.99926	8.20	9.20	17.40	125.00
Post Cold	10	5.6100	1.68948	5.20	3.20	8.40	56.10
Pre Warm	10	13.3600	2.24311	7.30	9.10	16.40	133.60
Post Warm	10	6.6300	1.99558	6.00	2.40	8.40	66.30

From the table above, it can be explained that the LD cold temperature therapy pretest data with a sample size of 10 obtained a mean value of 12.50, Std. Deviation 2.99, range 8.20, minimum value 9.20, maximum value 17.40, and total value (sum) 125.00. LD cold temperature therapy posttest data with a sample size of 10 obtained a mean value of 5.61, Std. Deviation 1.68, range of values (range) 5.20, minimum value 3.20, maximum value 8.40, and total value (sum) 56.10. LD warm temperature therapy pretest data with a sample size of 10 obtained a mean value of 13.36, Std. Deviation 2.24, range 7.30, minimum value 9.10, maximum value 16.40, and total value (sum) 133.60. LD warm temperature therapy posttest data with a sample size of 10 obtained a mean value of 6.63, Std. Deviation 1.99, range 6.00, minimum value 2.40, maximum value 8.40, and total value (sum) 66.30.

Before the data is analyzed, a prerequisite test is carried out to determine whether it can be analyzed using an independent sample t-test. The prerequisite tests are the normality test and the homogeneity test.

a. Normality Test

1) DN Data Normality Test

Table 4.
DN Normality Test Results

	Shapiro-Wilk		
	Statistic	df	Sig.
Cold Temperature	0.883	10	0.140
Warm Temperature	0.912	10	0.296

Based on the results of the normality test, it can be explained that in the data normality test with the Shapiro-Wilk test, the difference value of cold temperature therapy against DN obtained a statistical value of 0.883 and a significance value of 0.140> 0.05. Thus, the data is usually distributed. The difference value of warm temperature therapy against DN obtained a statistical value of 0.912 and a

significance value of 0.296> 0.05. Thus, the data is usually distributed.

2) RPE Data Normality Test

Table 5.
Hasil Uji Normalitas RPE

	Shapiro-Wilk		
	Statistic	df	Sig.
Cold Temperature	0.899	10	0.212
Warm Temperature	0.918	10	0.337

Based on the results of the normality test, it can be explained that in the data normality test with the Shapiro-Wilk test, the difference value of cold temperature therapy on RPE obtained a statistical value of 0.899 and a significance value of 0.212> 0.05. Thus, the data obtained is usually distributed. The statistical value of warm temperature on RPE is 0.918, with a significance value of 0.337> 0.05; thus, the data obtained is usually distributed.

3) LD Data Normality Test

Table 6.
LD Normality Test Results

	Shapiro-Wilk		
	Statistic	df	Sig.
Cold Temperature	0.949	10	0.660
Warm Temperature	0.939	10	0.544

Based on the results of the normality test, it can be explained that in the data normality test with the Shapiro-Wilk test, the difference value of cold temperature therapy on LD obtained a statistical value of 0.949 and a significance value of 0.660> 0.05. Thus, the data obtained is usually distributed. The statistical value of warm temperature on LD is 0.939, and a significance value of 0.544> 0.05. Thus, the data obtained is generally distributed.

b. Homogeneity Test

1) Homogeneity Test DN

Table 7.
DN Homogeneity Test Results

Levene Statistic	df1	df2	Sig.
2.009	3	36	0.130

Based on the results of the homogeneity test of the difference data of the cold temperature therapy group and warm temperature therapy against DN, the Levene statistic value is 2.009, with a significance value of 0.130> 0.05; it can be said that the data is homogeneous or comes from the same group.

2) RPE Homogeneity Test

Table 8.
RPE Homogeneity Test Results

Levene Statistic	df1	df2	Sig.
0.822	3	36	0.490

Based on the results of the homogeneity test of the data difference between the cold temperature therapy group and warm temperature therapy on RPE, the Levene statistic value is 0.822 with a significance value of 0.490> 0.05; it can be said that the data is homogeneous or comes from the same group.

3) LD Homogeneity Test

Table 9.
LD Homogeneity Test Results

Levene Statistic	df1	df2	Sig.
0.523	3	36	0.669

Based on the results of the homogeneity test of the difference data of the cold temperature therapy group and warm temperature therapy on LD, the Levene statistic value is 0.523 with a significance value of 0.669> 0.05; it can be said that the data is homogeneous or comes from the same group.

c. Hypothesis Test

The difference in the effect of the cold temperature therapy group and warm temperature therapy can be known by using the test to compare the effects of the two groups. Fatigue data in the form of pulse rate, Rating of Perceived Exertion, and blood lactate from the t-test can be seen in the following table.

Table 10.
T-test results of DN, RPE and LD data

Variables	group	N	Mean	SD	Sig
Post DN	Cold	10	72.60	10.15	
	Warm	10	81.20	14.85	0.049
Post RPE	Cold	10	9.60	1.07	
	Warm	10	10.20	1.31	0.003
Post LD	Cold	10	5.61	1.68	
	Warm	10	6.63	1.99	0.006

From the information in the table above, it is found that the pulse variable (DN) for the cold temperature therapy group with an average value (mean) = 72.60, SD 10.15, and the warm temperature therapy group with an average value (mean) = 81.20, SD 14.85 and the significance value obtained is 0.049 <0.05. So, it is said that cold and warm temperature therapy have different effects on pulse rate (DN). So, there are differences in the impact of cold and warm temperature therapy on pulse rate (DN).

Rating of Perceived Exertion (RPE) variables for the cold temperature therapy group with an average value (mean) = 9.60, SD 1.07, and warm temperature therapy group with an average value (mean) = 10.20, SD 1.31 and the significance value obtained is 0.003 <0.05. So, there are differences in the effect of cold and warm temperature therapy on the Rating of Perceived Exertion (RPE).

While the blood lactate (LD) variable for the cold temperature therapy group with an average value (mean) = 5.61, SD 1.68, and the warm temperature therapy group with an

average value (mean) = 6.63, SD 1.99 and the significance value obtained is 0.006 < 0.05. So, there are differences in the effect of cold and warm temperature therapy on blood lactate (LD).

The effectiveness of the cold temperature therapy group and warm temperature therapy can be known from the percentage difference between the pretest and posttest of each group. The formula used to determine the percentage of fatigue reduction is:

$$\% = \frac{(\text{Pretest} - \text{Posttest})}{\text{Pretest}} \times 100\ \%$$

Table 11.
Effectiveness test results of DN, RPE and LD data

Variables	group	N	(sum) Pretest	(sum) Posttest	Selisih	Persentase
DN	Cold	10	1236	726	510	0.412%
	Warm	10	1260	812	448	0.355%
RPE	Cold	10	158	96	62	0.392%
	Warm	10	170	102	68	0.400%
LD	Cold	10	125.0	56.1	68.9	0.551%
	Warm	10	133.6	66.3	67.3	0.503%

Based on the table above, it can be seen that the cold temperature therapy group DN has a percentage value of 0.412%, RPE has a percentage value of 0.392%, and LD has a percentage value of 0.551%. While the warm temperature therapy group on DN has a percentage value of 0.355%, RPE has a percentage value of 0.400%, and LD has a percentage value of 0.503%. Based on the percentage results obtained, cold temperature therapy is more effective in reducing DN and LD. Meanwhile, warm temperature therapy is more effective in lowering RPE.

Discussion

Based on the results of the hypothesis test, it is known that there is a significant difference in the effect between cold temperature therapy and warm temperature therapy on the fatigue recovery of badminton athletes. This can be seen from the significance value obtained, where the significance value obtained in the four groups on the pulse rate is 0.049, RPE is 0.003, and blood lactate levels are 0.006.

The warm temperature therapy group is the most influential in fatigue recovery compared to the cold temperature therapy group. This can be seen from the average value (mean) on the posttest obtained, where the average value (mean) in warm temperature therapy on DN 81.20, RPE 10.20, and LD 6.63 is smaller than the average value (mean) obtained from the cold temperature therapy group. Subjectively, cold and warm temperature therapy can reduce feelings of fatigue. (Bleakley et al., 2012) cold water stimulation given after physical exercise with structural fatigue can help facilitate the process of intracellular and intravascular fluid transportation, increase cardiac output without spending energy, increase blood flow and nutrients throughout the body, facilitate the flow of body waste disposal, accelerate the breakdown of lactate levels to speed up the recovery process. (Buchheit et al., 2009) Cold water immersion manipulation helps decrease the performance of capillary permeability in the body, which affects the low temperature of the prefrontal cortex in the brain, reducing tension in the brain nerves and reducing physiological responses. The body becomes relaxed, reducing cortisol hormone levels to reduce muscle spasms and muscle pain (delay onset muscle soreness) and accelerate the recovery cycle.

Meanwhile, warm water therapy can reduce muscle tension, dilate blood vessels, lower blood pressure, relieve joint pain, kill germs, and improve sleep quality (Harnani & Axmalia, 2017). The research results (Nurmaulina & Hadiyanto, 2021) state that foot soak therapy using warm water significantly lowers blood pressure. (Ferayanti et al., 2017) There is a significant effect on the decrease in systolic and diastolic blood pressure before and after being given foot soaking therapy with warm water and deep breath relaxation. Deep breath relaxation helps create a sense of calm and comfort, reducing pain and relaxing muscles to reduce tension, boredom, and stress.

Based on the results of hypothesis testing, it is known that cold and warm temperature therapy have different effectiveness in overcoming fatigue. The cold temperature therapy group is more effective in reducing DN and LD. Meanwhile, warm temperature therapy is more effective in reducing RPE. The existence of high activity without paying attention to adequate recovery time can cause a buildup of blood lactic acid, which results in obstruction of energy intake from the aerobic system in muscle cells and the onset of fatigue. This condition results in a decrease in muscle performance (muscle fatigue). Muscle fatigue during exercise can occur due to various causes, including depletion of energy stores from ATP, creatine phosphate, and glycogen; accumulation of lactate in muscles; disturbances in homeostasis such as plasma osmolality, plasma volume, decreased pH of body fluids and decreased electrolyte levels in body fluids; fatigue due to neuromuscular or central disorders; and fatigue due to environmental conditions, including temperature and humidity (Rasyid & Agung, 2017). (Fitrianto & Maarif, 2020) Muscle fatigue can also be caused by obstacles to blood flow to the contracting muscles carrying food and oxygen for fuel. Factors that play a role in muscle fatigue are the accumulation of lactic acid and the depletion of muscle energy reserves.

Based on the research results presented in the Discussion section, the hypothesis regarding the significant difference between cold and warm temperature therapy in the fatigue recovery of badminton athletes was confirmed. However, it's important to note that the research has some limitations. The sample size was relatively small, and the study was conducted over a short period of time. These limitations should be

considered when interpreting the findings. Hypothesis testing showed a significant difference between the two therapy methods, with significance values for pulse rate (DN) 0.049, Rating of Perceived Exertion (RPE) 0.003, and blood lactate level (LD) 0.006 - all below 0.05. Warm temperature therapy was found to be the most influential in fatigue recovery, as seen from the lower mean post-test scores compared to cold temperature therapy.

However, in terms of effectiveness, cold temperature therapy was superior in reducing DN and LD, while warm temperature therapy was more effective in reducing RPE. Both therapeutic methods have different physiological mechanisms in aiding recovery, such as facilitating fluid transport, increasing blood flow, decreasing capillary permeability, and reducing muscle tension. Thus, although both therapy methods showed significant differences in fatigue recovery, their effectiveness varied depending on the fatigue indicators measured.

Recovery is a crucial point of the training process. In addition to pure rest with passive lectures, several strategies and methods have been proposed for athletes to improve the recovery of muscle function after training and competition (Atradinal & Sepriani, 2017). Recovery with the proper method with a high level of fatigue can restore the body's metabolism to normal or even more optimal (Farhansyah, 2016).

Conclusion

Based on the research results described in the discussion, it can be concluded that there is a significant difference in the effect of cold temperature therapy methods and warm temperature therapy on the recovery of Badminton athletes' fatigue. There are differences in the effectiveness of cold and warm temperature therapy methods in recovering badminton athletes' fatigue.

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