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The Impact of Cold Water Immersion Duration on Heart Rate and Blood Pressure

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Abstract: One of the most frequently used recovery methods for athletes is Cold Water Immersion (CWI). The duration of immersion affects the body's response. However, the difference in duration of cold water immersion on pulse rate and blood pressure as indicators of recovery has not been widely discussed in previous studies. This study aims to determine the effect of CWI duration on pulse rate and blood pressure values after soccer training. The method used is a True experimental pretest post-test control group design. The subjects were soccer players from "Diklat Diponegoro Muda" aged 15-18 years. Players were divided into 3 groups using simple random sampling, including 5-minutes CWI (n = 11), 10-minutes CWI (n = 11), and a control group (n = 15). The primary data collected were systolic, diastolic, and pulse rates. Systolic showed no significant difference. Diastolic and pulse rates showed significant differences, with 10-minutes CWI being more significant. CWI duration significantly impacted diastolic and pulse rates, but not systolic. Ten-minutes CWI was more effective than five-minutes CWI and the control. Soccer players can perform 10-minutes CWI at 15-20°C to achieve significant results.

Keywords: Cold Water Immersion, Heart Rate, Blood Pressure

Introduction

Health is one of the most important things for humans (Daga et al., 2023). Well-maintained health can improve physical fitness, thus encouraging a person to be active. Physical fitness can be improved through physical activities such as exercise (Sinuraya & Barus, 2020). Exercise requires a lot of movement, making it very beneficial in improving and maintaining one's physical abilities. Furthermore, exercise can maintain mental health and serve as entertainment (Zuhri, 2023). One popular sport enjoyed by almost everyone, both in Indonesia and internationally, is soccer. Soccer is played for 2 x 45 minutess, with a 2 x 15 minutes break in certain situations. There is a 15-minutes break between the two halves. During the game, players strive to maximize their body movement and use their strength, such as by running or jumping (Bahtra, 2022). Maximal physical activity accompanied by short rest periods can lead to fatigue unless immediate recovery is provided (Syaefulloh & Purbodjati, 2022).

Exercise can alter a person's circulatory, respiratory, and metabolic systems. Physical activity during exercise improves heart performance. The increased need for blood to transport oxygen to active body tissues increases heart performance, increasing heart rate and blood pressure (Zahra et al., 2022). Pulse rate and blood pressure increase in proportion to the load placed on the body. Increased body performance can be a precursor to fatigue (Umam & Kafrawi, 2020). Conversely, if a person rests after physical activity, the frequency of these two indicators will decrease (Samodra & Sudrazat, 2021). Fatigue often affects athletes and individuals after high-intensity activity. Fatigue can occur along with aches, pains, heat, redness, swelling, and even injury (Wijaya & Supriyono, 2023). Injuries in sports pose a risk of increased body abnormalities due to field accidents or off-field factors that can lead to decreased player performance (Nur & Bakti, 2021). Therefore, recovery is crucial for soccer players. After engaging in high-intensity physical activity, recovery is essential to restore the body to its original state. One simple therapeutic method that can be used to restore the body's condition after playing soccer is cold water immersion (CWI).

CWI can reduce pain, swelling, and relax the body (Kusuma et al., 2020). Typically, immersion is performed for 5-10 minutess, 11-15 minutess, or 20 minutess, or adjusted to each individual's ability. The duration of immersion affects the body's response (Zuhri, 2023) (Jinnah et al., 2019). Accelerated recovery can be measured after exercise or therapy (Koesherawati et al., 2022). The effect of cold water immersion duration on pulse rate and blood pressure, indicators of recovery, has not been widely discussed in previous research. Researchers wanted to determine the effect of cold water immersion duration on pulse rate and blood pressure after soccer training, a high-intensity activity.

Method

The research method used a true experimental pretest-posttest control group design. The researcher explained and provided informed consent to prospective subjects on June 20, 2024, at Daleman Batursari Mraggen Field. The study was conducted on July 4, 2024, at Diponegoro University Stadium, once, from 2:00 PM to 6:00 PM WIB. The subjects were soccer players from the Diponegoro Youth Training Center in Semarang aged 15-18 who met the inclusion criteria. Subjects were divided into three groups using random sampling: 11 subjects in the 5-minutes CWI group, 11 subjects in the 10-minutes group, and 15 subjects in the control group. Subjects had their blood pressure and pulse measured before soccer practice, after soccer practice, and after recovery.

The research data was processed using IBM SPSS Statistics version 23. The researcher assessed the normality of data distribution using the Sapphiro-Wilk test and analyzed homogeneity using the Levene test. Normally distributed data is continued with the One-Way ANOVA difference test, if not normally distributed, the difference test is continued with the Kruskal-Wallis's test. Homogeneous data variance is continued with the Mann-Whitney test, if not homogeneous, the Game-Howell Post Hoc test is continued. The results of the significant difference test are continued with the Post Hoc LS test (Significant if $p < 0.05$).

Results & Discussion

Results

The data obtained were 37 subjects (100%), including 11 subjects in the 5-minutes cold water immersion group (29.7%), 11 subjects in the 10-minutes cold water immersion group (29.7%), and 15 subjects in the control group (40.5%). All subjects were male with the maximum age being 16 years. Measurement of the 3rd variable showed the lowest values in systolic (111.00 ± 15.26) and diastolic (67.76 ± 10.08) while the lowest measurement result in pulse was variable 1 (78.46 ± 12.74). The highest measurement was in variable 2.

Table 1. Descriptive Data

Variables	Frequency	%	Mean ± SD	Median (min – max)
Groups				
5-minutes group	11	29,7		
10-minutes group	11	29,7		
Control	15	40,5		
Age			16,00 ± 0,88	16 (15 – 18)
1st Systolic			115,19 ± 1chr3,05	116 (86 – 140)
2nd Systolic			126,32 ± 14,63	126 (97 – 148)
3rd Systolic			111,00 ± 15,26	110 (70 – 138)
1st Diastolic			69,32 ± 7,54	70 (54 – 83)
2nd Diastolic			77,51 ± 7,72	76 (62 – 96)
3rd Diastolic			67,76 ± 10,08	68 (47 – 96)
1st Pulse / Heart Rate			78,46 ± 12,74	78 (56 – 99)
2nd Pulse / Heart Rate			115,73 ± 13,38	113 (93 – 147)
3rd Pulse / Heart Rate			87,08 ± 18,16	86 (56 – 130)

Systolic Data Testing

In the first, second, and third systolic cycles, the Shapiro-Wilk and Levene tests yielded p values > 0.05, concluding that the data were normally distributed and had homogeneous variance. The difference test was continued using one-way ANOVA. In the first, second, and third systolic cycles, the p values were > 0.05, concluding that there were no significant differences.

Table 2. Systolic Normality and Homogeneity Test Data

Systolic	Group	Mean ± SD	Median (min – max)	p	Levene
1st	5 minutes	115,73 ± 15,66	113 (86 – 140)	0,950*	0,596**
	10 minutes	114,82 ± 13,01	118 (95 – 130)	0,102*	
	Control	115,07 ± 11,88	116 (94 – 135)	0,968*	
2nd	5 minutes	126,27 ± 11,28	123 (108 – 143)	0,201*	0,113**
	10 minutes	123,73 ± 17,96	132 (98 – 146)	0,088*	
	Control	128,27 ± 14,83	131 (97 – 148)	0,455*	
3rd	5 minutes	107,18 ± 11,93	104 (90 – 124)	0,447*	0,473**
	10 minutes	110,00 ± 14,50	110 (90 – 129)	0,249*	
	Control	114,53 ± 17,92	114 (70 – 138)	0,195*	

Description: * Significant (p < 0,05); ** Homogeneous (p > 0,05)

Table 3. Systolic Differences with One Way Anova Test

Systolic	Group			p
	5 minutes	10 minutes	Control	
1st	115,73 ± 15,66	114,82 ± 13,01	115,07 ± 11,88	0,986
2nd	126,27 ± 11,28	123,73 ± 17,96	128,27 ± 14,83	0,748
3rd	107,18 ± 11,93	110,00 ± 14,50	114,53 ± 17,92	0,476

Diastolic Data Testing

In the first and third diastolic cycles, the data were normally distributed and the variances were homogeneous, so we continued with one-way ANOVA and post-hoc LSD tests. In the second diastolic cycle, the data were normally distributed, and the variances were not homogeneous, so we continued with a difference test using one-way ANOVA and the Game-Howell post-hoc test. There were no significant differences between the first and second diastolic cycles, while there were significant differences in the third diastolic cycle. The post-hoc LSD test table between the 10-minutes group and the control group showed a significant difference.

Table 4. Diastolic Normality and Homogeneity Test Data

Diastolic	Group	Mean ± SD	Median (min – max)	p	Levene
1st	5 minutes	68,91 ± 8,20	70 (54 – 79)	0,114*	0,998**
	10 minutes	70,27 ± 7,46	69 (61 – 82)	0,394*	
	Control	68,93 ± 7,57	67 (60 – 83)	0,141*	
2nd	5 minutes	73,82 ± 2,82	73 (69 – 78)	0,248*	0,029
	10 minutes	79,45 ± 9,73	79 (66 – 96)	0,681*	
	Control	78,80 ± 8,04	78 (62 – 96)	0,483*	
3rd	5 minutes	66,91 ± 5,79	67 (57 – 78)	0,984*	0,209**
	10 minutes	61,73 ± 8,33	63 (49 – 75)	0,814*	
	Control	72,80 ± 11,47	72 (47 – 96)	0,937*	

Description: * Significant (p < 0,05); ** Homogen (p > 0,05)

Table 5. Diastolic Differences with One Way Anova Test

Diastolic	Group			p
	5 minutes	10 minutes	Control	
1st	68,91 ± 8,20	70,27 ± 7,46	68,93 ± 7,57	0,889
2nd	73,82 ± 2,82	79,45 ± 9,73	78,80 ± 8,04	0,164
3rd	66,91 ± 5,79	61,73 ± 8,33	72,80 ± 11,47	0,016*

Description: * Significant (p < 0,05)

Table 6. Difference in 3rd Diastolic Blood Pressure between Groups using Post Hoc LSD Test

Group		p
I	II	
5 minutes	10 minutes	0,195
	Control	0,116
10 minutes	Control	0,005*

Description: * Significant (p < 0,05)

Pulse Rate Data Testing

The first pulse rate showed a Shapiro-Wilk and Levene's test with a p value > 0.05, indicating a normal distribution and homogeneity of variance. The second pulse rate, in the 10-minutes group, showed a p value < 0.05, and the Levene's test > 0.05, concluding that the data were not normally distributed and the variance was homogenous. The third pulse rate, in the 5-minutes group, showed a p value < 0.05, and the Levene's test > 0.05, concluding that the data were not normally distributed and the variance was homogenous.

The first pulse rate was further analyzed using a one-way ANOVA and a post-hoc LSD test. The second and third pulse rates were further analyzed using the Kruskal-Wallis and Mann-Whitney tests. There were no significant differences between the first and second pulse rates, but a significant difference was found in the third pulse rate. The third pulse rate was further analyzed using the Mann-Whitney test. The Mann-Whitney test showed a significant difference between the 5-minutes group and the 10-minutes group and the control group, and a significant difference between the 10-minutes group and the control group. Therefore, the 10-minutes CWI was the most significant.

Table 7. Pulse / Heart Rate Normality and Homogeneity Test Data

Pulse / Heart Rate	Group	Mean ± SD	Median (min – max)	p	Levene
1st	5 minutes	76,91 ± 13,74	78 (56 – 96)	0,578*	0,709**
	10 minutes	73,73 ± 11,65	72 (58 – 99)	0,556*	
	Control	83,07 ± 11,97	83 (64 – 98)	0,167*	
2nd	5 minutes	116,18 ± 15,73	113 (93 – 146)	0,258*	0,250**
	10 minutes	113,09 ± 9,19	117 (94 – 122)	0,044	
	Control	117,33 ± 14,66	117 (99 – 147)	0,310*	
3rd	5 minutes	89,36 ± 12,70	89 (74 – 122)	0,039	0,149**
	10 minutes	67,00 ± 6,57	67 (56 – 77)	0,831*	
	Control	100,13 ± 14,08	98 (83 – 130)	0,266*	

Description: * Significant (p < 0,05); ** Homogen (p > 0,05)

Table 8. Pulse / Heart Rate Difference

Pulse / Heart Rate	Group			p
	5 minutes	10 minutes	Control	
1st	76,91 ± 13,74	73,73 ± 11,65	83,07 ± 11,97	0,163
2nd	116,18 ± 15,73	113,09 ± 9,19	117,33 ± 14,66	0,876
3rd	89,36 ± 12,70	67,00 ± 6,57	100,13 ± 14,08	<0,001*

Table 9. Difference in the 3rd Pulse between Groups

Group		P
I	II	
5 minutes	10 minutes	<0,001*
	Control	0,022*
10 minutes	Control	<0,001*

Description: * Significant (p < 0,05)

Discussion

The analysis results showed no significant differences because the three recovery groups were in the same condition before exercise, namely in a normal state without any treatment. All three recovery groups were given the same exercise and training treatment for 2 x 30 minutess, so the results of the difference test were not significant. Blood pressure increased due to increased cardiovascular demand and the process of oxygen uptake from the muscles. Sympathetic activity and increased heart rate cause cardiac output to increase. Furthermore, based on Poiseuille's law, increased cardiac output and stroke volume can cause vasodilation of skeletal muscle arteries and increase tissue to accommodate increased blood flow, resulting in an increase in arterial pulse pressure (Sherwood, 2018) (Mohammed et al., 2020). There was no statistically significant difference, although measurements showed a decrease in systolic blood pressure after recovery. This occurs because CWI affects peripheral vasoconstriction more, while systolic blood pressure is more influenced by cardiac output than peripheral resistance (Manjareeka & Mishra, 2014). In the control group, natural recovery occurred with parasympathetic activation that decreased cardiac output, resulting in a gradual decrease in systolic blood pressure. CWI causes peripheral vasoconstriction and sympathetic nerve activation, which increases systolic blood pressure in the initial minutess in response to cold stimulation. The body then adapts, causing systolic blood pressure to decrease or return to normal. In CWI, longer immersion durations and more extreme temperatures can provide more significant results (Machado et al., 2016), (Peiffer et al., 2009), (Yeung et al., 2016), and (Arpin et al., 2020). This study used a temperature range of 15–20°C with 5- and 10-minutes duration groups. Less extreme temperatures and durations, coupled with CWI's insignificant effect on systolic blood pressure, could be contributing factors to the insignificant data analysis results and the inconsistency of the researcher's hypothesis.

There was a significant difference in diastolic blood pressure after recovery in the three groups. The body's primary response to cold exposure is peripheral vasoconstriction, thus affecting diastolic blood pressure more (Yeung et al., 2016). This is consistent with previous research using the cold pressor test, where most subjects' diastolic blood pressure responded statistically more than systolic blood pressure. The comparison of 5-minutes CWI with 10-minutes CWI was not significant, contrary to the researchers' hypothesis. In CWI, cooling triggers the sympathetic nervous system, causing vasoconstriction and a temporary increase in blood pressure. The body then quickly adapts. When the body reaches a new equilibrium at a certain point, the body becomes more stable, so blood distribution throughout the body slows, and additional immersion time has only a minimal impact. Furthermore, the relatively small difference in immersion time at less extreme temperatures can also influence statistical results (Arpin et al., 2020) (Šrámek et al., 2000) (Sugawara & Tomoto, 2020). The results of the 5-minutes CWI comparison with the control group did not differ significantly, contrary to the researchers' hypothesis. A 5-minutes CWI at 15-20°C is not long enough to produce significant changes. Without immersion, blood pressure during the recovery period can naturally decrease, with the magnitude of the decrease varying from individual to individual and inconsistent (Syaefulloh & Purbodjati, 2022) (Šrámek et al., 2000). The results of the 10-minutes CWI comparison with the control group differed significantly, in line with the researchers' hypothesis. Physiological changes in blood flow mechanisms can depend on water temperature, immersion time, and the type of CWI (Machado et al., 2016). The effects of cold-water immersion are significant when performed for longer durations (Peiffer et al., 2009).

There were significant differences in heart rate across the three recovery groups. Heart rate is responsive to rapid physiological changes, one of which is post-exercise recovery. CWI induces an autonomic nervous system response that alters heart rate. When immersed in cold water, vasoconstriction occurs, slowing blood flow throughout the body and controlling pulse recovery (Syaefulloh & Purbodjati, 2022) (Koesherawati et al., 2022). Systolic and diastolic blood pressure tend to be more stable than pulse rate. Both are influenced by longer-term factors, so short-term changes are less significant. Blood pressure distribution is more normal, while greater pulse variability leads to significantly different results.

Conclusion

Before exercise, systolic blood pressure, diastolic blood pressure, and pulse rate between the subject groups did not differ significantly, indicating that the baseline conditions of the players were similar, namely in normal conditions. After exercise, systolic blood pressure, diastolic blood pressure, and pulse rate of the subjects increased. The measurement results between the groups did not differ significantly, indicating that the 2 x 30-minutes physical activity treatment produced similar results, namely an increase in cardiovascular response. After recovery, systolic blood pressure did not show a significant difference, while diastolic blood pressure and pulse rate showed significant differences between the recovery groups. The duration of CWI significantly affected diastolic blood pressure and pulse but not systolic blood pressure.

A 10-minutes CWI was more effective in reducing blood pressure, especially diastolic blood pressure and pulse rate. The application of CWI for recovery can be suggested as an alternative, especially to reduce blood pressure and pulse rate. Although a 10-minutes CWI showed more significant results, a 5-minutes duration can be considered as an option for rapid recovery. Further research with a larger subject or different durations can be conducted to further investigate the effects of CWI, especially on systolic blood pressure, which was not very significant in this study. Further research could provide a longer interval between subjects during exercise and recovery so that when data collection occurs, there is no bias in the results due to the players' condition possibly having returned to normal.

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