Physiological Changes during the Performance of Water Exercises in Different Water Temperatures

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Abstract

A study was conducted to investigate the changes in heart rate (HR) and blood pressure (BP) in the human body during the performance of physical exercise in water of different temperatures. The subjects performed two kinds of exercises: Upper Body Exercise (UBE) and Large Muscle group Exercise (LME) for 10 minutes at moderate intensity and for 30 seconds at maximum intensity; at water temperatures of 26, 30 and 36°C in separate routines. The exercise repetition was counted manually, while HR was automatically measured by wireless electrocardiograph and BP by an automatic sphygmomanometer. While water temperature appears to have a direct effect on work capability and HR, this effect was not observed in the case of BP.

Key words
blood pressure, heart rate, water exercise, water temperature

Introduction

In many rehabilitation and therapeutic programs water exercises have been adopted and have quickly become popular. However, the ideal water temperature for performing physical exercises is still not clearly established. According to Skinner and Thomson the recommended water temperature for orthopaedic and spinal injury cases should be between 34 and 36°C.[1] The average water temperature in heated pools suggested by Sova ranges from more than 21°C to less than 32°C.[2] Konishi's recommended temperature for hydrotherapy and rehabilitation is 37°C.[3]

In the available literature there is little scientific research focussing on the relationship between water temperature and its physiological effects on the human body when performing physical activities.[4-8] That being so, we decided to investigate such a relationship and furthermore, to determine the

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water temperature suitable for the performance of therapeutic and rehabilitative physical exercises in a water environment, for it has been found that water temperature may influence the results of a prescribed treatment.[1)]

Method

Five men and four women, ranging from 20 to 35 years of age, participated in the experiment.The experiment was conducted in a 11,000 liter immersion pool with the height of the water adjusted to be level with each subject's shoulders. Each subject performed a sequence of exercises in water at 26, 30 and 36°C, maintaining the water temperature within a deviation of ±1°C of the designated value. Room temperature was kept between 25~26°C.

During the testing sessions, starting from the initial position – standing with feet shoulder width apart and flexing the knees slightly – the subjects performed two kinds of exercises: a) upper body exercise (UBE), i.e. holding a float with each hand and placing the floats under the armpits while adducting and abducting the arms; b) large muscle group exercise (LME), arms semi-flexed along the body, hugging both knees together towards the chest, and returning to the initial position. These exercises were chosen because the subjects could easily maintain uniform repetition in terms of physical movement. UBE and LME were performed for 10 minutes at moderate intensity and, also for 30 seconds at maximum intensity. Exercise intensity was determined according to each subject's own pace, and the number of repetitions in each exercise was counted. Each subject performed a single sequence of exercises in water at 26, 30 and 36°C, on different days for each temperature.

During the performance of the exercises, heart rate was determined from electrocardiograph that were recorded from each subject using a wireless electric cardiograph (Wireless eletric cardiograph DS-882, Fukuda Denshi Co Ltd.), while blood pressure readings were obtained through the use of an automatic BP measurement machine (Automatic sphygmomanometer ABPM-630, Nippon Colin Co Ltd.).

The subjects observed the following procedural routine: a) rest outside the pool; b) enter the pool and rest for five minutes; c) perform the UBE at moderate intensity for 10 min. (UBE 10); d) after performing the task leave the pool and rest for five minutes; e) enter the pool again and rest for five min.; f) perform the UBE at maximum intensity for 30 seconds (UBE 30); g) after performing the exercise leave the pool and h) rest outside the pool for five minutes. For the LME (LME 10 and LME 30) the same routine was observed. All subjects firstly performed the UBE at moderate and maximum intensities and secondly the LME at the same intensities, at the same water temperature on the same day.

Heart rates were obtained before entering the pool, after resting for five minutes in the pool and during the performance of moderate intensity exercises at three, six, nine and ten minutes. HR was also obtained at 15 and 30 seconds during the maximum intensity exercise. Blood pressure was measured after the rest period of five minutes in the pool and immediately after completing the exercises.

After each day of workout all subjects answered a Subjective Questionnaire, which consisted of the following questions:

a) Question 1 – Could you relax when you were resting in the water?

b) Question 2 – How did you feel regarding the temperature of the water?

In the analysis of the collected data regarding the performance of two different exercises (UBE and LME) in three different water temperatures (26, 30 and 36°C), t-test and ANOVA were employed. T-test was applied in order to analyze the data of

the exercise groups among the aforementioned water temperatures. Regarding the results found through the employment of ANOVA, a certain reservation should be observed since the sample is of limited size.

Results

This experiment shows the following results of variance which are summarized on Table 1.

Before the performance of the exercises there was no statistically significant difference in heart rate among subjects, whether considered by gender or by water temperature.

After the subjects had rested for five min. immersed in water, there was a difference in HR across both gender and water temperature ($p<0.001$). A significant difference was also observed in systolic blood pressure (BPS) and diastolic blood pressure (BPD) after five minutes immersed in water, with regard to both gender ($p<0.001$) and water temperature ($p<0.05$).

The number of repetitions varied significantly at UBE 10 by gender (t-test; $p<0.05$) and water temperature (t-test; $p<0.01$), and at LME 30 by gender (t-test; $p<0.001$) and water temperature (t-test; $p<0.05$). Regarding the number of repetitions, on the whole we observed that at 26°C the subjects performed the highest number of repetitions for both UBE and LME except for UBE 10 in men; and at 36°C occurred the lowest number of repetitions for all of the exercise groups except for LME

Table 1 Summary of the results by ANOVA

Measurements		Factors				Covariate HR and BP at the beginning of the performance			R^2/adj.R^2
		Gender	Water temperature	Exercise	Interaction	HR	BPS	BPD	
During rest outside the pool	HR	ns	ns	ns		–	–	–	.140/.000
After resting 5 min. in the water	HR	.000	.001	ns		–	–	–	.356/.180
	BPS	.000	.017	ns		–	–	–	.422/.264
	BPD	.000	.012	ns		–	–	–	.422/.264
Differences of HR and BP at the beginning and ending of UBE10 and LME10	HR	.017	ns	.000		–	–	–	.543/.423
		.002	.017	.000		ns	–	–	.583/.461
	BPS	ns	ns	ns	Gender and exercise	–	–	–	.246/.049
		ns	ns	ns	Gender and exercise	–	.000	–	.461/.303
	BPD	ns	ns	ns		–	–	–	.199/.000
		ns	ns	ns		–	–	.000	.465/.309
Differences of HR and BP at the beginning and ending of UBE30 and LME30	HR	ns	ns	ns		–	–	–	.186/.000
		.006	ns	.019		.001	–	–	.381/.200
	BPS	ns	ns	ns		–	–	–	.195/.000
		.000	ns	ns		–	.000	–	.551/.419
	BPD	ns	ns	.009	Gender and water temp.	–	–	–	.353/.184
		ns	ns	.044	Gender and water temp.	–	–	.001	.513/.371

HR = heart rate; BPS = systolic blood pressure; BPD = diastolic blood pressure; UBE10 = upper body exercise for 10 minutes; LME10 = large muscle group exercise for 10 minutes; UBE30 = upper body exercise for 30 seconds; LME30 = large muscle group exercise for 30 seconds; ns = not significant.

10 in women, as shown in Figures 1 and 2.

The heart rate reached the highest level at 36°C and the lowest at 30°C during and after exercise (t-test; $p<0.01$ in LME 10, and LME 30 after exercise, as shown in Figures 3 to 6).

In Figures 7 to 10 we can see the findings regarding blood pressure and the variance of water temperature. There is a certain tendency for blood pressure to decrease with an increase in water temperature. In response to exercise, results indicate that blood pressure did not show clear differences in the three water temperatures.

During the performance of UBE 10 and LME 10 at moderate intensity, heart rate had a significantly different variation by gender ($p<0.01$), by water temperature ($p<0.05$), and by type of exer-

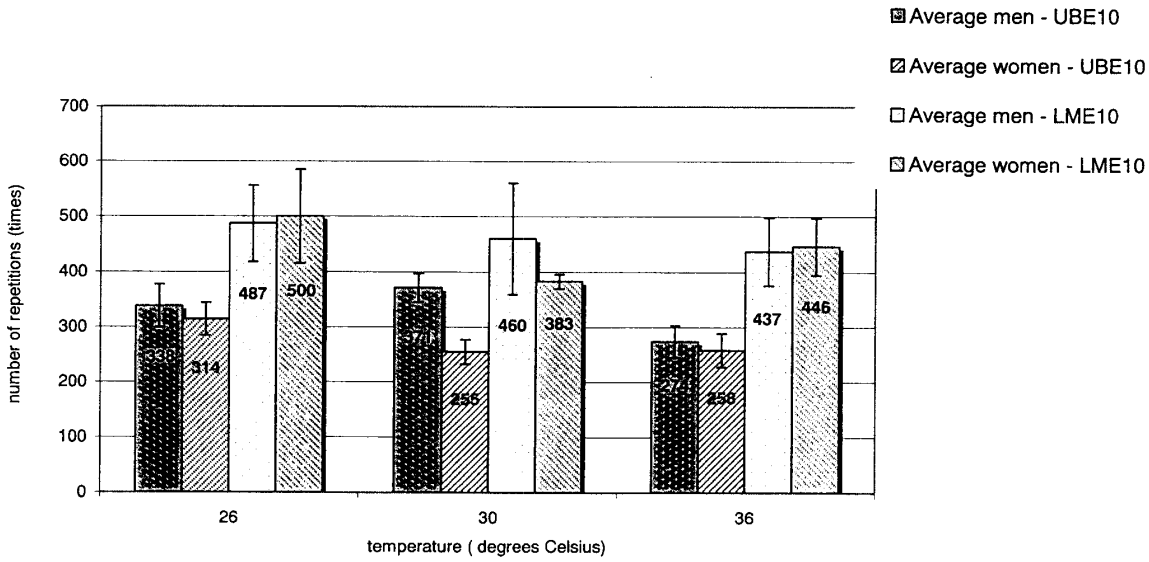

Fig. 1 Number of Repetitions of UBE10 and LME10 according to Temperature

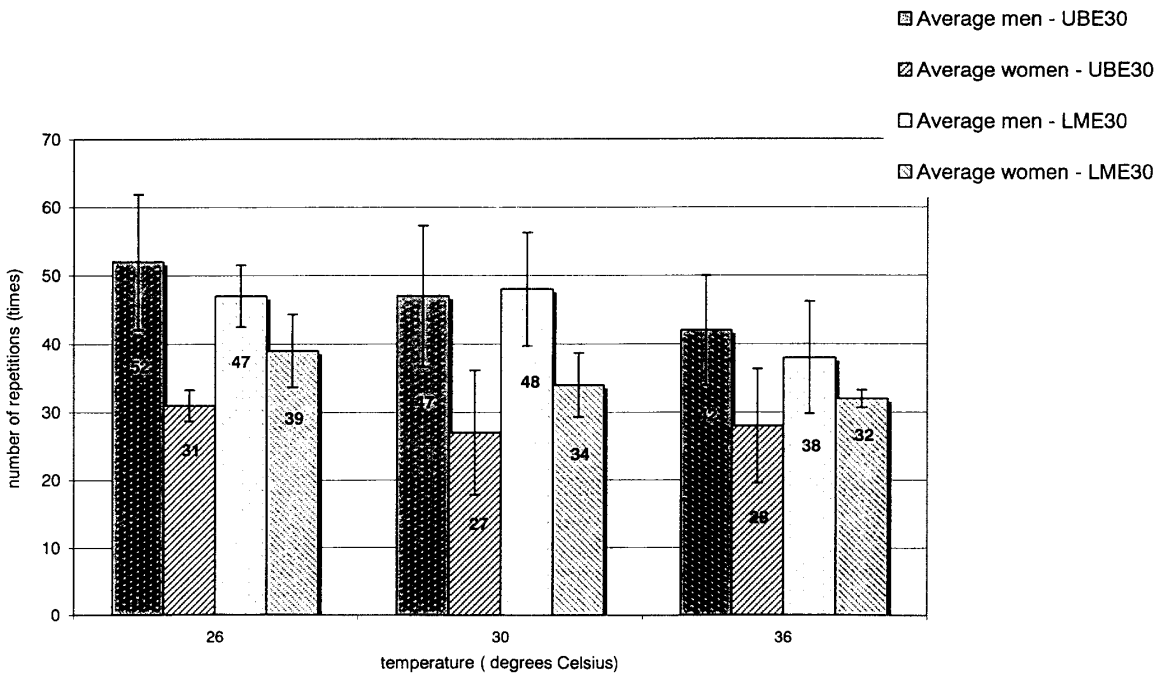

Fig. 2 Number of Repetitions of UBE30 and LME30 according to Temperature

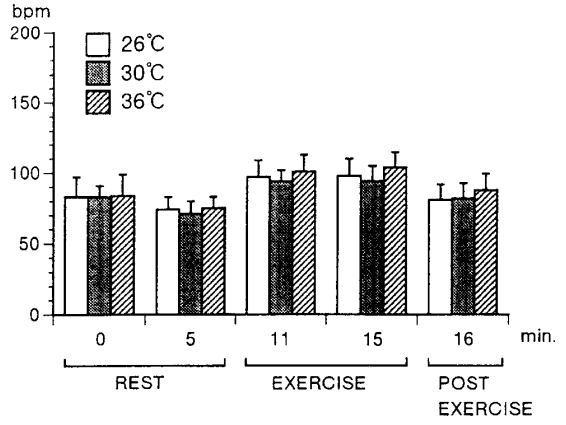

Fig. 3 Heart Rate – UBE 10 minutes

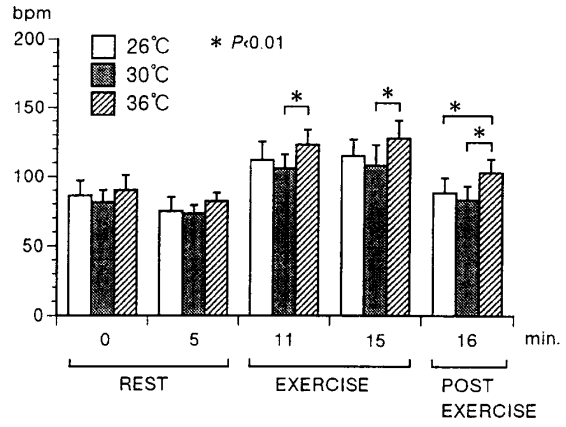

Fig. 4 Heart Rate – LME 10 minutes

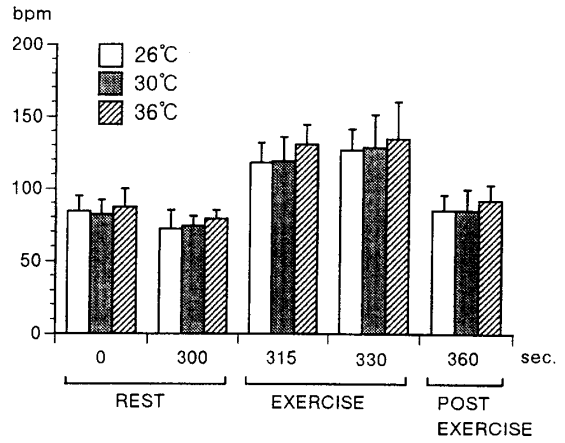

Fig. 5 Heart Rate – UBE 30 seconds

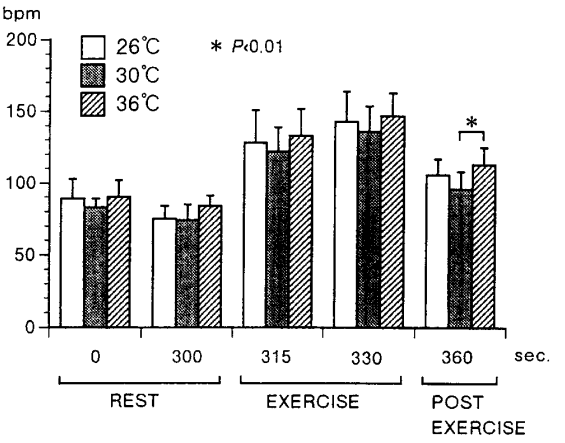

Fig. 6 Heart Rate – LBE 30 seconds

cise ($p<0.001$). Concerning blood pressure (BPS and BPD), no statistically significant differences between gender, between different water temperatures and between exercises was verified. At UBE 10 heart rate and blood pressure presented a significant difference by gender. Also, at LME 10 heart rate showed a significant difference by gender ($p<0.05$), however no significant difference was detected in blood pressure.

During the performance of UBE 30 and LME 30 at maximum intensity, heart rate and blood pressure did not present any significant difference by gender or by water temperature. However, at LME 30 we verified a significant difference in the variation of heart rate by gender ($p<0.05$).

The analysis of the Subjective Questionnaire produced the following results:

a) Question 1 – Could you relax when you were resting in the water? All subjects reported that at 26°C they felt very cold during the resting period in the water, as a consequence, none of them felt that they could relax properly; at 30°C all subjects, except one, felt that they could relax; and at 36°C all subjects felt that they could relax.

b) Question 2 – How did you feel regarding the temperature of the water? During the resting period at 26°C all subjects reported that the water was very cold and all subjects developed piloerection and reported feeling chilled. However, after the performance of exercises the subjects did not feel cold at all, reporting that they felt very comfortable exercising at this temperature. At 30°C,

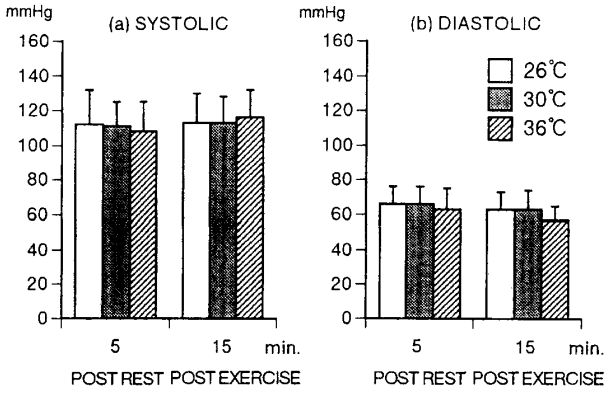

Fig. 7 Blood Pressure – UBE 10 minutes

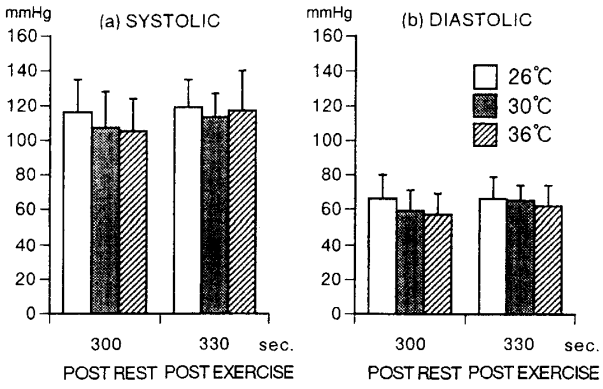

Fig. 9 Blood Pressure – UBE 30 seconds

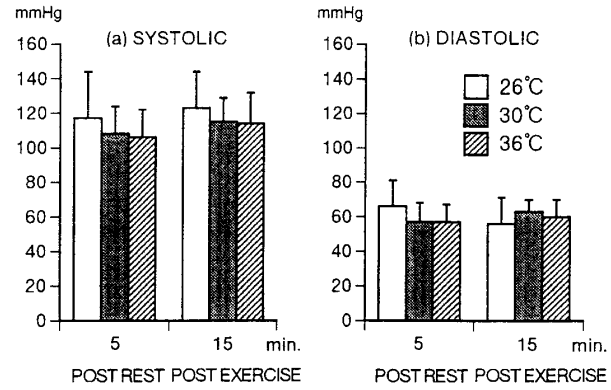

Fig. 8 Blood Pressure – LME 10 minutes

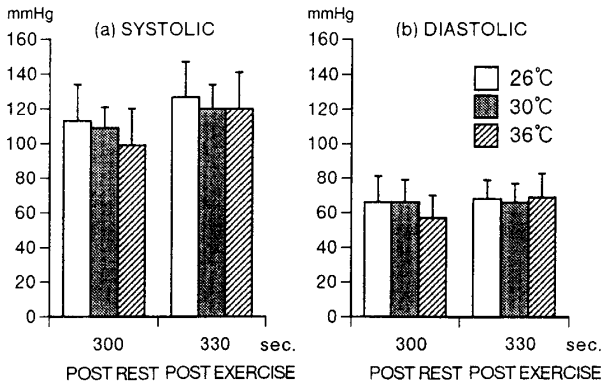

Fig. 10 Blood Pressure – LME 30 seconds

six out of nine of the subjects reported that the water was pleasant and three out of nine reported it was cold. At 36°C all subjects reported that the water was hot but comfortable during the resting period, however, after performing UBE and LME they complained of heat and discomfort.

Discussion

We could verify from our results that the performance of UBE 10 and LME 10 presented a significant difference with regard to both water temperature and gender. Therefore, we consider that the water temperature has a direct effect on work capability, that is, in the number of repetitions of exercise. Due to the excellent work capability showed in our results at water temperature of 26°C, workout in standing position are more advisable to be performed in this temperature.

In rehabilitation and therapeutic programs the warmth of the water appears to produce relaxation and relieves pain in the joints, thus facilitating the execution of physical movements.[1] This factor makes a water temperature at 26°C unsuitable for rehabilitation and therapeutic programs since relaxation is very important, and our experiment demonstrated that the water at 26°C produces a feeling of coldness and relaxing is impossible. Results have shown that the subjects could relax at 30 and 36°C; for this reason, these temperatures would be more ideal for rehabilitation programs. When comparing work capability at 30°C with that at 36°C subjects showed better outcome at 30°C. HR levels during exercise at 30°C are lower than at 36°C then, it seems more advisable for rehabilitation patients to perform physical exercises in water at a

temperature close to 30°C. If 30°C is not comfortable, then 36°C or less is recommended. It should be borne in mind that HR increases proportionally to the increase of water temperature[6-8] and also increases according to the severity of the physical activity.[1] Considering these factors, lower water temperatures seem to be proper for the execution of rehabilitation exercises.

Analysis of the data regarding blood pressure verified that the differences were not significant between the data collected after the resting period and after performing exercises. In this study it was showed that at 26°C the BP was higher than at the other two temperatures. This was expected to happen, because exposure of the human body, immersion in this case, to cold temperatures causes vasoconstriction of peripheral blood vessels.

Conclusions

This experiment shows that the ideal water temperature for rehabilitation and therapeutic programs using physical exercises in water varies between 30 and 36°C. Since relaxation is important in this kind of program, and just one subject could not properly relax in water at 30°C, a water temperature at 30°C or a little higher should be advisable.

According to our results, blood pressure did not vary significantly during the performance of physical exercise in water and at temperatures chosen in this study.

Even though work capability showed better results at 26°C in this study, this temperature is not recommended for rehabilitation and therapeutic programs due to people's inability to relax at such a low temperature.

We assume that some limitations may have occured to affect the results of the present study. Firstly, we presumed that the HR variation was due to difference of the water temperature and the exercises' performance, however, it could be also related to different cadence of activity and/or different metabolic load. In spite of that, we were enable to control these effects. Secondly, the exercise's intensity was based on each subject's own pace and it could be affected by the subject's effort at the time we conducted the sessions of our study. Finaly, we should carefully interprete the results using ANOVA, since our sample size and our statistical power were small.

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