Effects of Low-intensity Exercise in the Morning on Afternoon Exercise Performance

Manabu Sakai1, Kazuki Nishimura2, Koji Nagasaki3, Hidetaka Yamaguchi4, Akira Yoshioka5, Sho Onodera6 and Noboru Takamoto7

1Department of Civil Engineering and Urban Design, Hiroshima Institute of Technology (2-1-1 Miyake, Saeki-ku, Hiroshima 731-5193, Japan)
m.sakai.a5@it-hiroshima.ac.jp
2Department of Global Environment Studies, Hiroshima Institute of Technology (2-1-1 Miyake, Saeki-ku, Hiroshima 731-5193, Japan)
3Department of Food Sciences and Biotechnology, Hiroshima Institute of Technology (2-1-1 Miyake, Saeki-ku, Hiroshima 731-5193, Japan)
4Department of Sports Social Management, Kibi International University (8 Igamachi, Takahashi-city, Okayama 716-8508, Japan)
5Interactive Sport Education Center, Okayama University (2-1-1 Tsushima-naka, Kita-ku, Okayama 700-8530, Japan)
6Department of Health and Sports Science, Kawasaki University of Medical Welfare (288 Matsushima, Kurashiki-city, Okayama 701-0193, Japan)
7Department of Clinical Engineering, Hiroshima Institute of Technology (2-1-1 Miyake, Saeki-ku, Hiroshima 731-5193, Japan)

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This study examined the effects of low-intensity exercise in the morning on exercise performance in the afternoon. Fifteen healthy men were exposed to two measurement conditions: 30 min of bicycle exercise at 40% of maximum oxygen consumption (morning exercise) or rest in the sitting posture (control) at 8:30 AM. Physiological parameters were measured at 4:00 PM with the participant at rest in the supine position. Physical fitness tests and anaerobic power tests began at 4:30 PM. The two conditions demonstrated no significant difference in heart rate, systolic or diastolic blood pressure, double product, total power of R-R interval variability, ln HF (index of cardiovascular parasympathetic nervous system activity), or oral temperature. Morning exercise was associated with significantly better 20-m shuttle run, standing long jump, and sit-and-reach performance compared to the control condition. No significant differences in other physical fitness tests were observed. Thus, participants had significantly higher total physical fitness test scores and significantly greater maximum anaerobic power under the morning exercise condition. Our results indicate that low-intensity exercise in the morning might enhance afternoon exercise performance and may be considered an effective conditioning method on the day of a sporting event.

Keywords: low-intensity exercise, morning exercise, physical fitness tests, anaerobic power

1. Introduction

In humans, body temperature, heart rate, blood pressure, and other physiological parameters follow circadian rhythms consisting of approximately one cycle per day, with the human autonomic nervous system switching from a parasympathetic-dominant state during nighttime sleep to a sympathetic-dominant state during daytime waking (Baik et al., 2006; Vandewalle et al., 2007; Yamaguchi et al., 2009). The basic circadian rhythm is body temperature, which is lowest during nighttime sleep just before awakening (4:00 to 6:00 AM); subsequently, body temperature increases, reaches its peak at approximately 4:00 to 6:00 PM, and decreases again (Weinert and Waterhouse, 2007). We have previously reported that the consumption of breakfast and low-intensity exercise in the morning causes body temperature to peak earlier in the day; studies have shown that these factors, along with others such as exposure to sunlight in the morning, are important in circadian rhythm entrainment.
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(Nishimura, 2014). Previous studies have reported that many factors affecting exercise performance are entrained based on circadian rhythms, with grip strength peaking at approximately 7:00 PM (Ilmariinen et al., 1980), anaerobic capacity at 9:00 PM (Hill and Smith, 1991), and whole-body reaction time at 9:00 PM (Yanagimoto and Ebisu, 1994). Moreover, jumping power, agility, flexibility, and cardiorespiratory endurance are reported to be significantly lower at 8:00 AM than at 6:00 PM (Kato et al., 1993). These studies suggest that exercise performance should fluctuate over the course of the day, and the best performance is usually noted from late afternoon to nighttime.

Previous studies on the sustained influence of exercise have found that blood pressure is lower after moderate-intensity aerobic exercise than before exercise (a phenomenon termed as post-exercise hypotension) (Halliwill et al., 2013), that oxygen intake increases for several hours after exercise (a phenomenon called excess post-exercise oxygen consumption) (Vianna et al., 2014), and that exercise changes the dynamics of hormone secretion (Jensen and Richter, 2012). Moreover, strength training has been shown to damage muscle fibers, which typically results in muscle pain (Nosaka et al., 2007). However, to our knowledge, no previous study has been performed on the sustained influence of exercise in terms of the physiological responses that occur during subsequently performed exercise. One example of such an effect would involve the effect of morning exercise on exercise performance in the afternoon.

Many previous studies have indicated that vigorous early-morning exercise poses a cardiovascular risk (Muller et al., 1989; Shimada et al., 2001; White, 2000; Yamaguchi et al., 2009). However, in rule of thumb in competitive sports, low-intensity exercise in the early morning is considered a useful conditioning method that enhances performance and boost training effects. In fact, when training for a competition, many competitive athletes engage in walking or other low-intensity exercise in the morning after awakening, particularly on the day of a competition. Despite this widespread practice, we could not find any previous studies on the effects of low-intensity exercise in the morning on subsequent athletic performance. Thus, there is no definitive scientific evidence supporting its positive effects. What particular athletic abilities might be improved by light morning exercise is also unclear. Therefore, we hypothesized that low-intensity exercise in the morning would enhance afternoon exercise performance and attempted to verify this hypothesis using tests of physical fitness.

2. Methods

The participants consisted of 15 men with a mean age of 21.9 ± 1.3 years, mean height of 169.3 ± 7.9 cm, mean body weight of 64.6 ± 9.9 kg, and mean body mass index of 22.5 ± 3.3 kg/m². All participants were normotensive, non-obese, and nonsmokers, with no evidence of cardiovascular disease based on their medical history or resting electrocardiogram; all subjects performed regular exercise. In accordance with the Declaration of Helsinki, the men provided written consent to participate in the study after receiving an explanation of its objective and methods, the expected effects, the risk-free environment, and protection of personal information.

We established two measurement conditions for each participant: 30 min of bicycle exercise at 40% of maximum oxygen consumption at 8:30 AM (morning exercise condition) and rest in a sitting posture during this time (control condition). Measurements under the two conditions were made in random order 1 week apart. Under both conditions, participants went to bed at 11:00 PM the night before the experiment and arose at 7:00 AM. Participants also ate a specially prepared breakfast (629 kcal, 19.2 g protein, 16.5 g fat, 100.9 g carbohydrates, 1.3 g sodium) at 7:30 AM and a specially prepared lunch (647 kcal, 19.5 g protein, 20.8 g fat, 94.6 g carbohydrates, 2.8 g sodium) at 12:30 PM. Participants were given 10 min to eat their meals and were not allowed to eat or drink anything other than what was provided. On the day the measurements were taken, participants were not allowed to nap; however, they were instructed to restrict their physical activity to a minimum and to spend their time quietly, such as by reading a book or attending a lecture while seated.

Heart rate, blood pressure, double product, cardiovascular autonomic nervous system activity, and oral temperature were measured at 4:00 PM with the participant at rest in the supine position. Heart rate was defined as the number of R waves in 1 min on electrocardiogram waveforms, which were obtained using bipolar chest leads (LRR-03 memory...
heart rate monitor; Arm Electronics, Tokyo, Japan). It was recorded over a 5-min interval, and the mean value was recorded for analysis. Blood pressure was measured with an automated sphygmomanometer (Omron HEM-7420; Omron Healthcare, Kyoto, Japan); two measurements were performed, and the mean was recorded for analysis. The double product was defined as the product of mean heart rate and systolic blood pressure. Cardiovascular autonomic nervous system activity was measured with the maximum entropy calculation method, using the MemCalc/Tarawa software system for real-time analysis of heart rate fluctuation (GMS, Tokyo, Japan). The electrocardiogram data obtained and amplified from bipolar chest leads were digitized using a 12-bit analog-to-digital converter (AD12-8(PM); Contec, Qinhuangdao, China) and loaded into a personal computer (IBM, Armonk, NY, USA) running Microsoft Windows XP. Through this system, the frequency analysis of R-R interval variability over the last 30 s was performed with MemCalc, wherein the powers of the low-frequency (LF; 0.04–0.15 Hz) and high-frequency (HF; 0.15–0.40 Hz) bands of the variability spectrum were calculated based on a previous study (Pomeranz et al., 1985). The LF and HF components were summed to obtain the total power of R-R interval variability, which was used as an indicator of the level of cardiovascular autonomic nervous system activity. In addition, the HF component, which was converted to a natural logarithm (ln HF) to ensure a normal distribution, was used to indicate the level of cardiovascular parasympathetic nervous system activity (Nishimura et al., 2011). In order to exclude the effect of respiratory rate on cardiovascular parameters, an electronic metronome was used to pace respiratory rate at 1 breath every 4 s (2 s of inspiration and 2 s of expiration) (Brown et al., 1993; Hayano et al., 1994). Oral temperature was measured using a digital thermometer (MC-672; Omron Healthcare).

From 4:30 to 6:30 PM, we conducted physical fitness tests and maximum anaerobic power test. After initial measurements were taken, participants spent 10 min warming up in the manner of their choosing. The physical fitness tests were performed according to the standards of the Japan Ministry of Education, Culture, Sports, Science, and Technology (1999). Tests were performed in the following order: grip strength, sit-ups, sit-and-reach, side-to-side jumps, 50-m dash, standing long jump, 20-m shuttle run, and anaerobic power test. The length of rest periods between tests was decided by the participants.

Grip strength was measured twice on each side using a digital grip force meter (EKJ077, Evernew, Tokyo, Japan). Sit-up performance was measured as the number of times the participants succeeded in raising the upper body in 30 seconds. Sit-and-reach performance was measured using a long-seat body anteflexion measurement instrument (T-2649, Toei Light, Saitama, Japan). Side-to-side jump performance was measured as the number of jumps achieved in 20 s. Performance on the 20-m shuttle run was measured using equipment from Takei Scientific Instruments (TK-11454; Niigata, Japan). Performance on the 50-m dash was measured in ds using a stopwatch. Performance on the standing long jump was measured in cm by the distance jumped from the takeoff line. The maximum anaerobic power test was performed using the POWERMAX-VIII anaerobic training machine (Combi, Tokyo, Japan). Maximum anaerobic power was approximated by a linear regression of 3 different load values (Y) and the number of pedal rotations at maximum effort (X). The values with the largest products of X and Y were recorded and used for statistical analysis. The room temperature and humidity were 23.6 ± 1.8°C and 29.5 ± 5.9%, respectively.

Measurements are represented as mean ± standard deviation. The means for each item were compared between conditions using the paired-samples t-test. The threshold for statistical significance was set at < 5%.

3. Results

In morning exercise condition, participants’ mean heart rate during exercise was 126.8 ± 6.0 bpm. Table 1 displays the effects of low-intensity morning exercise (or lack thereof) on physiological parameters measured at rest in the supine position at 4:00 PM. The two conditions demonstrated no significant differences in heart rate, systolic or diastolic blood pressure, double product, total power of R-R interval variability, ln HF, or oral temperature.

Table 2 displays comparisons of all physical fitness tests between the morning exercise and control conditions. Participants performed significantly better on the 20-m shuttle run, standing long jump, and
Table 1  The effects of low-intensity exercise in the morning on resting physiological parameters.

| Parameter                      | C condition (Mean ± SD) | E condition (Mean ± SD) | p-value |
|--------------------------------|-------------------------|-------------------------|---------|
| Heart rate (bpm)               | 60.9 ± 9.3              | 63.5 ± 8.4              | 0.114   |
| Systolic blood pressure (mmHg) | 118.7 ± 5.4             | 116.5 ± 10.6            | 0.544   |
| Diastolic blood pressure (mmHg)| 64.9 ± 8.2              | 62.3 ± 5.4              | 0.489   |
| Double product (mmHg • bpm)    | 7,205 ± 1,024           | 7,371 ± 827             | 0.587   |
| Total power                    | 7.17 ± 1.36             | 7.06 ± 1.48             | 0.536   |
| ln HF                          | 6.42 ± 1.60             | 6.29 ± 1.70             | 0.226   |
| Oral temperature (°C)          | 36.63 ± 0.22            | 36.46 ± 0.36            | 0.195   |

C, control; E, exercise.

Table 2  Comparisons of physical fitness tests between control and exercise conditions.

| Test                          | C condition (Mean ± SD) | E condition (Mean ± SD) | p-value |
|-------------------------------|-------------------------|-------------------------|---------|
| 50-m dash (sec)               | 7.34 ± 0.39             | 7.34 ± 0.42             | 0.951   |
| Sit-ups (times)               | 32.9 ± 5.1              | 31.6 ± 5.0              | 0.149   |
| Grip strength (kg)            | 40.1 ± 6.5              | 39.7 ± 5.7              | 0.613   |
| Standing long jumps (cm)      | 216 ± 20                | 222 ± 20                | 0.008   |
| Side-to-side jumps (points)   | 58.6 ± 2.7              | 57.8 ± 3.3              | 0.100   |
| 20-m shuttle run (shuttles)   | 71.7 ± 15.5             | 77.0 ± 15.3             | 0.010   |
| Sit-and-reach (cm)            | 44.6 ± 9.0              | 46.9 ± 8.5              | 0.009   |

C, control; E, exercise.

Figure 1. Comparison of total physical fitness test scores between control and exercise conditions. *p<0.05. C, control; E, exercise.

Figure 2. Comparison of maximum anaerobic power between control and exercise conditions. *p<0.05. C, control; E, exercise.

sit-and-reach under the morning exercise condition than under the control condition (all p<0.05). No significant differences were observed between the two conditions for any other physical fitness tests. Figure 1 displays a comparison of total physical fitness test scores between the two conditions. Participants obtained a significantly higher total physical fitness test score under the morning exercise condition than under the control condition (p<0.05). Figure 2 displays a comparison of maximum anaerobic power between the two conditions. Participants had significantly greater maximum anaerobic power under the morning exercise condition than under the control condition (p<0.05).

4. Discussion

The results of the present study demonstrate that low-intensity exercise in the morning may enhance afternoon exercise performance.
In the present study, we set bicycle exercise intensity at 30 minutes and 40% of maximum oxygen consumption based on findings in previous studies. Previous studies have indicated that excessively vigorous early-morning exercise is associated with cardiovascular risks (Muller et al., 1989; Shimada et al., 2001; White, 2000; Yamaguchi et al., 2009). In addition, the ratio of the double product at 60% maximum oxygen consumption to the double product during rest was significantly higher in the morning than in the afternoon (Nishimura et al., 2011). Previous studies on circadian rhythms have determined that body temperature, grip strength, and other physiological parameters reach maximum values in the afternoon or evening (Hill and Smith, 1991; Ilmarinen et al., 1980; Yanagimoto and Ebisu, 1994). Accordingly, we asked participants to exercise in the afternoon, when exercise capacity is at its maximum. At 8:30 AM, each subject performed bicycle exercise based on a rule of thumb in competitive sports. Our findings warrant further studies to determine the effects of the intensity and duration of morning exercise, as well as the optimal period of the day for exercise to improve athletic performance.

We have previously reported that the consumption of breakfast and low-intensity exercise in the morning may cause the body temperature to reach its peak earlier in the day; studies have shown that these factors, along with others such as exposure to sunlight in the morning, are important in circadian rhythm entrainment (Nishimura, 2014). In the present study, all participants had their physiological parameters measured in the same room and ate the same breakfast, thus minimizing the effect of factors other than morning exercise. Given that there were no significant differences in physiological parameters between measurement conditions, low-intensity exercise in the morning appeared to have little effect on resting physiology. Thus, the impact of morning exercise might be comparatively small compared with diurnal fluctuations in physiological responses. However, we did not measure our participants’ changes in body temperature across different phases of their circadian rhythm, which limits the conclusions that can be drawn from our study.

Low-intensity morning exercise enhanced the total physical fitness test scores. The possible reasons for this finding include persistence of the effect of exercise and variations in physiological rhythms associated with exercise. Aerobic exercise forces the body to adapt functionally and structurally. When exercise begins, energy demand increases in the active muscles; the oxygen transported to these muscles by blood increases, and the structures of the respiratory and circulatory systems change to regulate oxygen supply. Furthermore, as exercise becomes a habit, the respiratory and circulatory systems adapt to training. In the present study, the effect of low-intensity exercise in the morning may have continued into the afternoon; however, as previously stated, only a minimal effect was observed on resting physiology. However, oral temperature peaks significantly earlier in the day in individuals who habitually consume breakfast and exercise than in those who do not (Nishimura, 2014). Previous studies have reported that jumping power, agility, flexibility, cardiorespiratory endurance, and anaerobic capacity are entrained based on circadian rhythms (Hill and Smith, 1991; Ilmarinen et al., 1980; Kato et al., 1993; Yanagimoto and Ebisu, 1994). We think it likely that the improvement in exercise performance following morning exercise observed in the present study was primarily associated with circadian variations rather than with the effects of the exercise. However, it is not known how the morning exercise in the present study might have affected body temperature or other aspects of circadian rhythm. Further study is necessary to determine the factors involved in the enhancement of afternoon exercise performance after morning exercise. In the present study, we set conducted physical fitness tests and maximum anaerobic power test from 4:30 to 6:30 PM based on a rule of thumb in competitive sports. In particular, as the tests in our study were performed only between 4 pm and 6 pm, further investigation should involve exercise performance tests conducted at other times of day.

In the present study, low-intensity exercise in the morning was significantly associated with enhanced afternoon performance in the 20-m shuttle run, sit-and-reach, standing long jump, and maximum anaerobic power, which improved by 8.1 ± 9.8%, 5.6 ± 6.9%, 3.2 ± 3.7%, and 5.9 ± 6.3%, respectively. These results suggest that low-intensity morning exercise might be able to induce prominent enhancement in cardiorespiratory endurance, flexibility, jumping power, and anaerobic exercise capacity. However, although improvements were observed on some tests, the difference was slight for others. Pos-
sible ways in which morning exercise may have been responsible for improvements include use of the same active muscles in the afternoon as in the morning or an impact on circadian rhythms (body temperature, the nervous system, metabolism, or hormone dynamics). After morning exercise, significant differences in oral temperature and heart rate were observed until 12 hours after exercise, and significant differences in ln HF (an indicator of parasympathetic nervous system activity with regard to the heart) were observed between groups after lunch intake (measurements taken at 1 and 2 pm). In contrast, no significant difference in systolic or diastolic blood pressure was observed between those who engaged in morning exercise and those who did not. In addition, there was no significant difference between groups with regard to changes to rectal temperature over a single day or with regard to total power, the latter being an indicator of autonomic nervous system activity associated with the heart. Morning exercise enhances the alertness of the cerebrum (Furuta et al., 2002) and is therefore believed to elevate body temperature, accelerate metabolism, increase the activity levels in the brain, and more. However, it is unclear whether these effects persist until 4 pm. Measurements taken while the participants were resting showed no significant differences in body temperature or autonomic nervous system activity after morning exercise, implying that diurnal fluctuations in metabolism and hormone dynamics were responsible for the observed improvements in exercise performance.

In conclusion, our study demonstrated that low-intensity exercise at 8:30 AM may enhance performance in certain exercises from 4:30 to 6:00 PM, thus supporting the idea that it may be an effective conditioning and training method for those who participate in sports. However, as other factors may be responsible for enhanced performance in the afternoon, further studies with larger samples and more variables are needed.

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Name: Manabu Sakai

Affiliation: Department of Civil Engineering and Urban Design, Hiroshima Institute of Technology

Address: 2-1-1 Miyake, Saeki-ku, Hiroshima, 731-5193 JAPAN

Brief Biographical History:

(1994-) Assistant Professor at Hiroshima Institute of Technology

(1979-1981) Master’s Program, Graduate School of Coaching Science, University of TSUKUBA

(1974-1978) Undergraduate Program, Department of Education, University of HIROSHIMA

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