THE JOURNAL OF
SWIMMING RESEARCH

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Editor's Preview

The paper by Gambrel, et al concerns a comparison of two relay starts: the conventional start vs. a “step-start” in which one foot is placed back on the block and brought forward to the front of the block during the initial part of the start sequence. Hypothesizing that this “step-start” mat move the swimmer’s center of mass forward earlier and over a greater distance, the authors conducted a study to determine if there is a performance advantage associated with this “step-start”. The so-called “bottom line” of this study was that the time to reach 10 meters was about seven hundredths of a second faster, on average, when using the step-start. This difference was not statistically significant, meaning that there was greater than 5% probability that the difference was due to chance. One wonders, therefore, if some swimmers in the group were substantially faster using the step-start while others were faster with the conventional start. If this is true, a future study could attempt to identify swimmers who perform better with the step-start and evaluate whether their faster performance is reproducible over several trials. Then, a conclusion might be reached that suggests that some swimmers benefit from using a step-start while others should stay with the conventional start.

Circadian rhythms (or cyclic fluctuations in physiological functions during the day) are well documented for many physiological and psychological functions. Some research suggests swimming performance is also influenced by circadian rhythms with faster performances generally observed later in the day. With this in mind, Reilly and Marshall conducted a study to evaluate whether 30 second power output on a Biokinetic Swim Bench conforms to a circadian rhythm. The findings show the lowest power scores at 6:00 and highest scores expected between about 14:00 and 18:00 (2-6 pm). Certainly these findings should be considered whenever researchers or coaches design a power testing or monitoring program and imply that testing should always be conducted at the same time of day. Although not examined in this study, it would be useful to know if the circadian rhythm in power and performance can be altered by adjustment of the time of day when practices are scheduled and the type of work in these practices. In other words, is it possible to convert an “evening” person to a “morning” person or flatten out the circadian rhythm so that the swimmer’s physiological potential is as great for morning prelims as it is for evening finals?

Rick Sharp
A Biomechanical Comparison of Two Relay Starts in Swimming

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Abstract
The purpose of this investigation was to identify the mechanical characteristics of the step start in relay competition and to compare this start to a conventional relay start. Seven trained college age males from the University of Nebraska Collegiate Swim Team volunteered to perform eight racing dives, four demonstrating the step start and four demonstrating the conventional start. Although no statistically significant differences (p < .05) were found for any of the parameters, a comparison of the group means indicated that when swimmers performed the step start, they had the longest block times and the largest horizontal velocities. The angle at take-off and the path of the center of mass (COM) varied to a greater extent between subjects when using the step start. A slightly longer flight distance also resulted from using the step start. However, group means for the flight times remained the same. It was concluded that the step and conventional starts are very similar in their performance parameters. It was further concluded that the step start at its present level of development is as good as the conventional start for relay competition.

Introduction
Over the years competitive swimmers have utilized various nutrition regimens, training methods, stroke techniques, starting styles and turning techniques to improve their racing performance. These activities influence an individual’s racing time by hundredths of a second, which may be the difference between winning and losing, or even breaking a world record. Competitive swimmers have also used a variety of starting techniques to improve racing times.

Specific rules govern the relay events. The freestyle and medley relay teams are comprised of four swimmers, each swimming one-fourth of the prescribed distance. The first swimmer must abide by the rules governing the start for the individual events. The remaining swimmers may be in motion at the start, but must have at least one foot in contact with the starting platform at the time the preceding swimmer finishes.

For those competing in individual events and for the first member of a relay team a good start is primarily the responsibility of the swimmer on the block, assuming the starter follows the rules established by the N.C.A.A. However, in relay events, the responsibility of a good start for the second, third, and fourth team members is shared between the incoming and outgoing swimmers. The incoming swimmer’s responsibility is to finish in a predictable and practiced manner which is obvious to the outgoing swimmer.

Over the past two years coaches from the University of Nebraska at Lincoln have developed a different relay start. This starting technique was coined the “step start” because it was descriptive of the actions of the lower extremities prior to take-off. As the incoming swimmer approaches the wall the swimmer atop the starting platform assumes a position in which the legs are staggered, with the toes of the front foot curled over the front edge of the platform and the back foot positioned to the rear of the platform. The swimmer’s knees are slightly flexed,
with the neck and trunk inclined in a forward and downward position. In this position the center of mass (COM) is placed over the back foot. The initial movement of the swimmer is to thrust the rear foot forward to a position adjacent to the front foot. This begins the forward movement of the COM. Once the foot secures a firm contact with the platform the knees, ankles, and hips extend, while the arms move forward and upward driving the COM over the surface of the water.

Some coaches believe the step start moves the swimmer’s COM earlier in the start and over a larger distance. This could result in a greater velocity of the COM as the swimmer’s feet leave the platform.

As the swimmer becomes more competitive, the importance of reducing the overall time of an event becomes apparent. The ability to improve a relay racing start is considered important to competitors seeking to reduce the overall relay time. To this date, racing starts have been analyzed on only an individual event basis, leaving relay event starts unresearched. The purpose of this investigation was therefore to identify the mechanical characteristics of the step start in relay competition and to compare this start to a conventional relay start.

Methods

Subjects

The subjects for this study were seven college age males with at least eight years of competitive swimming experience. All were members of the University of Nebraska at Lincoln swimming team. All of the swimmers had previous experience with both conventional and step starts. All subjects had been taught the step start by Keith Moore (assistant coach for the Nebraska swimming team) and were currently using this start in relay competition while using the conventional start for individual competition.

Experimental Procedure

Subjects were scheduled for one testing session. Upon arrival each subject provided informed consent in accordance with the procedures required by the Institutional Review Board of the University of Nebraska. Each subject was then weighed and had his height measured. In order to control the effect of learning and fatigue in the testing session each subject was randomly assigned to one of two starting orders (step start first or conventional start first). The assignment was made in accordance with the sampling without replacement procedure as described by Keppel (6). Prior to testing, each subject was read a script of specific instructions. After listening to the instructions, the swimmers were asked to warm up as they would prior to any competition. Subjects were randomly divided into two groups. One group consisted of four swimmers and the other consisted of three. Each subject performed eight trials, four demonstrating the step start and four demonstrating the conventional start. A trial consisted of a swimmer in the water swimming the crawl stroke at full speed to the end of the pool at which time a subject from atop the starting block dove and swam (approximately three arm strokes) to a bulkhead. Each subject was instructed to complete all four trials of the start chosen in the randomization before performing the other start. The subjects rotated within their group, first from the pool deck to the starting block, then to the water. In the event of a false start, the trial was repeated. This rotation continued until all eight trials of the subjects within the group were completed.

Instrumentation

High speed cinematography was used to determine the swimmer’s movements. A LoCam, model 51, 16mm camera with a 25mm F1.4 lens was mounted on a tripod and leveled. The camera contained an internal timing light generator set to mark the edge of the film at 100Hz. The camera was located at a distance of 16.1 meters from the center of the swimming lane. At this distance the starting position atop the block and entry of the subject’s fingertips into the water were completely within the field of view of the camera. The camera was positioned perpendicular to the swimming lane at a point halfway between the swimmer’s position at take-off and water entry. The position of the camera remained consistent for all trials. The camera was loaded with Kodak 7277 4x reversal black and white film and was set to operate at 100 frames per second. A trial identification marker and one meter length reference were also included in the camera’s field of view. Lighting consisted of the natatorium ceiling lights and four high intensity Pallite VIII lamps with an output of 2400 watts each.

The processed film was displayed on a Lafayette Data Viewer rear projection system. The frame rate and scale factor were calculated from the film. X and Y coordinates for 17 anatomical landmarks were recorded every other frame (two hundredths of a second) beginning with the fortieth frame prior to take-off and ending at water entry.

Parameters Measured and Calculated

Block time was the time from the incoming swimmer touching the wall to the time the subject’s feet left the starting block.

Center of mass was determined by segmental analysis derived from X and Y coordinates of 17 identified anatomical landmarks.

Flight time was the time elapsed from the frame in which the subject’s feet left the platform to when his fingertips made water entry.

Time to 10 meters was the time from the subject’s feet leaving the platform at take-off to the subject’s fingertips contacting a touchpad secured to a bulkhead 10 meters from the front edge of the starting block.
Angle of the COM at take-off was the angle determined by plotting the position of the COM at take-off and two hundredths of a second after take-off related to the horizontal.

Height of the COM at take-off was determined by measuring the vertical distance from the surface of the water to the COM at take-off.

Height of the COM at water entry was determined by measuring the vertical distance from the surface of the water to the COM at water entry.

Horizontal velocity of the COM at take-off was determined by measuring the horizontal distance the COM traveled from take-off to two hundredths of a second after take-off and dividing this value by the elapsed time.

Statistical treatment

Individual parameter values were calculated utilizing the mean of three of the four trials for each subject. In situations where all four trials were readable, the three trials demonstrating values closest to the mean time to 10 meters for all four trials were chosen for analysis. The mean and standard deviation for all three trials for each subject were calculated for all parameters. The mean and standard deviation for all subjects combined were then determined for each parameter. For each parameter, a dependent t-test was used to compare mean scores for the step start and conventional start. All comparisons were evaluated at the .05 level of significance.

Findings

Basic descriptive characteristics of each swimmer are presented in Table 1. The mean ± standard deviation for height and mass for the group were 190.38 ± 9.87cm and 80.32 ± 8.45kg respectively. Table 2 contains the group means, standard deviations, and t-test values for all the parameters of the step and conventional starts. Although no statistically significant differences (p < .05) were found for any of the parameters, a comparison of the group means indicated that the swimmers using the step start had the longest block times and were also able to accumulate the largest horizontal velocities. No differences were noted between group means for the height of the COM at take-off and water entry. Although the angle at take-off of the COM for the step and conventional start indicated no significant difference, the standard deviation of the step start was larger than that of the conventional start.

Although not significant, group means also indicated that time to 10 meters could be covered faster using the step start than using the conventional start. Group means further reveal that a slightly larger flight distance was covered using the step start than the conventional start. However, group means for the flight times were the same.

In addition to finding no significant differences be-

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Step X ± SD (N = 7)</th>
<th>Convention X ± SD (N = 7)</th>
<th>t*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block time (sec.)</td>
<td>0.16 ± 0.08</td>
<td>0.13 ± 0.06</td>
<td>1.691</td>
</tr>
<tr>
<td>Time to 10 meters (sec.)</td>
<td>2.96 ± 0.16</td>
<td>3.03 ± 0.15</td>
<td>-1.699</td>
</tr>
<tr>
<td>Height of COM at Take-off (meters)</td>
<td>1.40 ± 0.07</td>
<td>1.39 ± 0.05</td>
<td>1.268</td>
</tr>
<tr>
<td>Height of COM at Water Entry (meters)</td>
<td>0.76 ± 0.06</td>
<td>0.76 ± 0.06</td>
<td>.370</td>
</tr>
<tr>
<td>Horizontal Velocity of COM at Take-off (m/s)</td>
<td>4.57 ± 0.28</td>
<td>4.56 ± 0.15</td>
<td>.108</td>
</tr>
<tr>
<td>Horizontal Velocity of COM at Water Entry (m/s)</td>
<td>4.38 ± 0.19</td>
<td>4.30 ± 0.07</td>
<td>1.108</td>
</tr>
<tr>
<td>Flight Time (sec.)</td>
<td>0.42 ± 0.05</td>
<td>0.42 ± 0.04</td>
<td>.190</td>
</tr>
<tr>
<td>Flight Distance (meters)</td>
<td>1.81 ± 0.19</td>
<td>1.78 ± 0.18</td>
<td>.835</td>
</tr>
<tr>
<td>Angle at Take-off (degrees)</td>
<td>55.93 ± 1.43</td>
<td>55.81 ± 0.81</td>
<td>.163</td>
</tr>
</tbody>
</table>

*DF = 6
**p < .05
between block times for the step (0.16 ± 0.08 sec.) and conventional (0.13 ± 0.06 sec.) starts, the times were similar to those reported in the literature (0.18 ± 0.04 sec.) for the grab start (3). The height of the COM at water entry for both the step and conventional starts was 0.76 ± 0.06 meters. These values were somewhat larger than the values (0.59 ± 0.08 meters) found by Guimarães and Hay (2) in a study involving twenty-four high school students demonstrating the grab start.

Figure 1 represents the path of the COM from takeoff to water entry for each of the seven subjects utilizing the step start. Figure 2 represents the path of the COM from takeoff to water entry for each of the seven subjects using the conventional start. No significant differences were found between the height of the COM at takeoff and water entry. However, the path of the COM for subjects using the step start varied to a greater extent than the path of the COM for subjects using the conventional start.

No differences were found between the horizontal velocity at takeoff for the step start (4.57 ± 0.28 m/sec.) and the conventional start (4.36 ± 0.15 m/sec.). Both scores were similar (4.33 ± 0.61 m/sec.) to those found in research for the grab start by Havriluk and Ward (5).

Figure 3 and 4 illustrate the horizontal velocities from takeoff to water entry for each subject using the step and conventional start, respectively. It would appear that the horizontal velocities of the COM for the subjects using the conventional start varied to a greater extent than the horizontal velocities of the COM for the subjects using the step start.

No differences were found between the flight times for the step start (0.42 ± 0.05 sec.) and the conventional start (0.42 ± 0.07 sec.). Flight times were found to be somewhat slower than flight times found in the whip (0.34 ± 0.03 sec.), grab (0.30 ± 0.04 sec.), and swing (0.31 ± 0.06 sec.) starts among Canadian Olympic male swimmers (5).

All seven subjects when using the step start began with their COM higher than when using the conventional start. Four of these subjects continued to maintain a higher COM throughout the dive. Of the four subjects that maintained a higher COM throughout the entire dive, only one was able to project his COM further using the step start. Three subjects demonstrated a lower COM at two different locations in the path. One subject demonstrated a lower COM prior to takeoff while the
other two subjects demonstrated a lower COM from take-off to water entry. The two subjects that maintained a higher COM from take-off to water entry also projected their COM further from the starting block.

Six of the seven subjects using the conventional start were able to maintain larger horizontal velocities of the COM from take-off to water entry. Whereas, only one of the seven subjects using the step start was able to maintain a somewhat larger horizontal velocity of the COM from take-off to water entry. However, this same subject was able to produce a longer flight time using the conventional start.

Discussion

Research on racing starts in swimming has been limited primarily to individual events. Therefore, information on the start for the second, third, and fourth swimmer in relay events is very limited. Previous studies on racing starts have focused on traditional starting methods with the swimmer assuming a desired, motionless position atop the starting block prior to the official starting the race (1,2,3,5,7). The present study resulted from a need for quantitative information on relay starts that could be used as a baseline for comparisons and further study.

No significant differences were found between any of the parameters measured. However, mean times indicated that the longer the subject's block time, the greater the horizontal velocity and the longer the flight distances. In addition, no significant differences were found between the means for the angle at take-off of the COM. Therefore, it is not surprising that the mean flight distance between the step and conventional starts also displayed no significant difference. The slightly longer flight distance achieved by the subjects when using the step start was most likely due to the flight path since no difference in the take-off angle of the COM existed.

Plots of the horizontal velocities of the COM of each subject for the step and conventional starts illustrated an increase in velocity until take-off and then a slight decrease until water entry. This was expected since the subjects applied force against the platform in an attempt to move forward, but after leaving the platform they could no longer apply force and therefore slowed down.

The paths of the COM for the step and conventional start were similar for all seven subjects. The path of the COM prior to take-off demonstrated large differences in the height of the subject's COM until take-off. This is not surprising since all seven subjects exhibited a higher COM atop the starting block prior to take-off when using the step start. However, the height of the COM at take-off and water entry revealed no significant differences between starts. The path of the COM was consistent for both the step start and conventional start. However, the path of the COM for subjects using the step start varied to a greater extent than the path of the COM for the subjects using the conventional start. This fluctuation in the path of the COM when using the step start is felt to be a direct result of the subjects moving their COM over a larger distance atop the starting block during the stepping phase in which the rear foot moved to a position adjacent to the front foot.

Time to 10 meters also showed no significant differences between starts. Time to 10 meters is not only dependent upon horizontal velocity, but also upon water time. Water time was calculated by subtracting flight time from the time to 10 meters. This time resulted from the distance the subject traveled in the water and the subject's velocity in the water.

This research indicated that the step start at its present level of development showed no noticeable superiority to the conventional start. However, the results of this research indicated that it is at least as good as the "conventional" start. This finding was in fact exciting in that a new innovative technique was found to be as effective as the current standard. With years of refinement and practice, the step start may someday surpass the conventional start.

Summary

The purpose of this investigation was to evaluate the mechanical characteristics of the step start in relay competition and to compare this start to a conventional relay start. Seven college age males, all members of the University of Nebraska at Lincoln swimming team, were subjects for this study. All subjects were familiar with both starts and used both in competition. The subjects were free of any physical disability or ailment that might have caused any impaired performance. All subjects completed one testing session consisting of four filmed trials of both the step and conventional starts. High speed cinematography (100 frames/second) was used to film the subjects from a side view. Nine parameters were obtained from the processed film using standard cinematographic procedures. The results were summarized as follows:

1. No significant difference was found between the starts for block time. The values were within normal ranges from other studies (5).
2. No significant differences were found between the starts for the heights of the COM at take-off or at water entry.
3. No significant differences were found between the starts for either horizontal velocities at take-off or at water entry. Values of these parameters agreed with values presented for horizontal velocities at take-off and water entry from other studies involving college age male swimmers (5).
4. No significant differences were found between starts for flight time or flight distance.
5. No significant difference was found between starts for the angle at take-off.

Conclusions
For the sample of subjects in this study, the following conclusions were made:
1. The data indicated that the step and conventional starts for relay competition are very similar in their performance parameters.
2. From the results of this study the step start is as good as the conventional start for relay competition.

References
3. Hanauer, E.S. The grab start. *Swimming World and Junior Swimmer*, 1967, 8, 4-5, 42.

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Circadian Rhythms in Power Output on a Swim Bench

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Abstract

This study investigated the circadian variation in power output of swimmers and its relation to the circadian rhythms in body temperature and subjective alertness. The mean and peak power output of 14 competent swimmers was measured at 6 equidistant times of day using a swim-bench. Measurements were made pre-exercise of alertness, pulse rate and rectal temperature. Significant rhythms were observed in pulse rate (peak 14:00 hours), body temperature (peak 18:00 hours) and alertness (peak 18:00 hours) (all P < 0.001). Mean and peak power output showed corresponding circadian rhythms (peak 18:00 hours) with amplitudes 11 and 14%, respectively, of their mean values. Performance on the swim bench was not linked with subjects' preferences for morning or evening work. Findings have implications for the scheduling of swimmers' training regimens according to time of day.

Key terms: alertness, anaerobic performance, circadian rhythms, swim-simulator.

Introduction

Circadian rhythms reflect cyclical fluctuations in physiological functions over the course of the solar day. The major rhythms are those of body temperature and the sleep-wake cycle. The classical rhythm conforms to a sine wave or cosine function with a peak in the afternoon or evening and a trough at about mid-sleep. There is evidence that many human performance measures display circadian variation close in phase with the curve in body temperature (8).

Swimmers use the early morning and the evening in implementing their training programmes. It is likely that the propensity to undertake strenuous training loads does vary according to time of day with the main physiological rhythms. These rhythms could affect the intensity of the physiological stimulus presented during swim training. This would apply also to the stimulus provided in dry land training to improve muscular strength and power, using swim benches for example.

There is evidence that swimming performance is influenced by the time of day. Rodahl et al. (13) found that swimmers produced significantly faster times over 100 m at 17:00 hours compared with 07:00 hours in 3 out of 4 strokes studied. More frequent sampling at 5 different times of day between 06:00 hours and 22:00 hours demonstrated that performance improved steadily throughout the day (2). Sinnerton and Reilly (14) also showed that swimmers performed better in the evening at 17:30 hours than in the morning at 06:30 hours. Performances in front crawl were 3.6 and 1.9% faster for 400 m and repeated 50 m swim trials, respectively. This time of day effect was apparent through three experimental days of partial sleep deprivation.

There is also experimental support for the existence of circadian rhythms in a number of factors that constitute components of swimming performance. These include flexibility (4), muscular strength (15) and tolerance of high exercise levels (9). There are suggestions also that performance is affected by individual preferences for morning or evening work (6).

This study was conducted in order to:-

i) establish the existence of circadian rhythms in power output on a swim bench;

ii) examine the relation between circadian variation in performance and rhythms associated with body temperature and the sleep-wake cycle;

iii) determine the effect of circadian phase type on performance using the swim bench.
Methods

Fourteen subjects, 7 male and 7 female, aged 23 ± 3 years, volunteered to take part in the study after giving written informed consent. All had experience of competitive racing and were currently engaged in swim training. All subjects were familiar with training using a swim-bench (Isokinetics Inc., Albany, CA) prior to commencement of the study.

Each subject undertook an all-out test for 30 s on the “Biokinetic Swim Bench” (Isokinetics Inc.). The test sessions were conducted at six different times of day: 02:00, 06:00, 10:00, 14:00, 18:00 and 22:00 hours. Test administration was balanced so that no two subjects undertook the test in the same order. Between each test session a rest period of at least 24 hours was enforced and all tests for each subject were completed within a 3-week period. Diet, sleep and physical activity were controlled according to the procedures of Reilly and Brooks (11). Laboratory temperature was relatively constant at 18.3 (± S.D. = 0.4) °C for the duration of the experiment.

At each test session the 30 s test was performed twice, full recovery being allowed before the subject undertook the second test. Subjects had a standard warm-up prior to the test and in a preliminary visit had been familiarised with the test protocol. The test was performed with the speed setting at “4” on the swim bench. The peak power (over the first 5 s) and mean power (over the 30 s) were noted by monitoring the display on the swim-simulator. The modification of the standard anaerobic power and aerobic capacity test had previously been used with swimmers (10).

Prior to the exercise tests the subject relaxed for 10 min in a seated posture. At the end of this period pulse rate was measured by palpation, the mean of three 30 s periods being recorded. Subjective alertness was rated by subjects on a visual analogue scale, graded between alert and drowsy at the two extremes. Pre-exercise rectal temperature was recorded using a digital clinical thermometer (Phillips, Eindhoven). Circadian phase type was determined by questionnaire according to Horne and Ostberg (6).

Data were first analysed using a two-way analysis of variance. Where the effect of time of day was significant data were then analysed using cosinor analysis (7). Where the subjects effect was significant, values were corrected by normalising each subject’s data to the lowest observation. These procedures are in accord with the guidelines used by Akerstedt (1).

Findings

A significant circadian variation was observed in pulse rate, rectal temperature and subjective alertness (P < 0.001). The subjects effect was significant in the pulse rate data (P < 0.05). The acrophase (peak time) of the rhythms was computed to occur at 16:10, 16:50 and 18:10 hours for pulse rate, rectal temperature and subjective alertness, respectively (Table 1).

Mean (P < 0.001) and peak (P < 0.01) power values showed significant circadian variations (Table 2). When corrected for individual differences, highly significant rhythms were evident in both variables. The acrophases of the rhythms were 16:23 hours and 16:13 hours for mean and peak power respectively.

The responses to the circadian phase questionnaire disclosed there were 4 morning types, 4 evening types with 6 of the subjects being intermediate. There were no apparent differences in rhythms between the 3 groups. Both morning and evening types had similar mean heart rates which peaked at 14:00 hours. A similar result was noted for rectal temperature, highest values being observed at 18:00 hours. The rhythm in alertness appeared to be relatively constant from 14:00 hours onwards in the

<table>
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<th>Table 1</th>
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<td>Mean (± SD) values for pulse rate, rectal temperature and alertness at some different times of day (n = 14)</td>
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<tr>
<td>Variable</td>
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<tr>
<td>Pulse rate (beats min⁻¹)</td>
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<td>Rectal temperature (°C)</td>
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<td>Alertness</td>
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<td>Mean and peak power output during a 30 s all-out test on a ‘Biokinetic Swim Bench’ (n = 14). Values are mean (± S.D.) for each of the 6 times of day.</td>
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<td>Mean Power (W)</td>
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morning group whilst continuing to rise in the evening group, the difference between the 3 sub-groups was not significant (P > 0.05). Although the subjects with morning preferences had poorer anaerobic performances than the other two sub-groups, no differences were noticed in the variations occurring in power output during the day.

Discussion
This study showed that power output in short-term all-out efforts on a swim-simulator did display circadian rhythmicity. This applied to both peak power and mean power indices. The amplitude of the rhythm was 14% of the mean value for peak power and 11% of the mean power average. This variation with time of day is greater than that observed for arm (12) and leg exercise (5) on the Wingate Anaerobic test. It lends support to the view that the amplitude of circadian rhythms increase with the complexity of motor tasks.

The rhythms in power output were closely in phase with those of pulse rate, rectal temperature and alertness. In agreement with earlier work (11) the highest values for pulse rate were noted 4 hours earlier than those for rectal temperature. In the present study the 95% confidence limits of the three marker variables overlapped and the phase lead of pulse rate over the others was non-significant (P > 0.05). In view of the phase concordance of pulse rate, body temperature and alertness, the rhythm with the greatest influence on the fluctuations in power output could not be identified. According to Bergh and Ekblom (3) anaerobic power declines by 5% for every 1 °C drop in body temperature. It would appear that central factors such as are reflected in the rhythm in alertness contribute along with the body temperature rhythm to the circadian rhythm in power production on the swim bench.

There was no indication that the circadian rhythm in power output was influenced by circadian phase type. Conclusions have to be tentative in view of the small numbers that could be classed as morning types and evening types. Swimmers expressing negative attitudes towards morning training may have a need for external motivation by their coaches to help them achieve their training targets.

In summary, the circadian rhythm in power output on a swim bench was closely related to the circadian curve in body temperature and in alertness. Thus the performance rhythm is linked with both physiological and psychological factors. The existence of these rhythms should be taken into account by swimmers and their coaches when planning strength and muscular power training programmes.

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Abstract
The idea of a scientific journal specifically dedicated to enhance communication between scholars interested in competitive swimming, and the professional practitioners in the sport, i.e., coaches, originated from the late Keith Sutton. His vision was that JSR would serve the American and indeed the international swimming community by acting as an educational forum without a compromise in scientific rigor. In this way, JSR would serve researchers seeking an attentive, appreciative audience as well as serve those who wish to apply recent results obtained from the frontiers of science. One of Keith's original concepts is actualized by that which follows, a bibliography of publications relevant to the swim community. It is hoped that this bibliography continues to represent a useful guide to information relevant to coaches, swimmers and researchers. As always, suggestions which may improve the usefulness of this index to the swimming community are welcome.

Biomechanics


General


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