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# The acute effects of Suryanamaskar yoga and dynamic stretching on anaerobic performance of amateur cyclists

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**Abstract**

The purpose of this study was to investigate the acute effects of dynamic stretching (DS) and Suryanamaskar yoga (SK) on peak power output, mean power output, fatigue index (FI) and cycling speed revolution per minute (RPM) of amateur cyclists. Sixty participants were screened and randomly assigned into one of two groups, DS and SK. The participants in both groups performed baseline and a post –warm up standard 30-sec Wingate Maximum capacity test. The Wingate Maximum capacity test was tested at baseline and immediately after the intervention. According to the findings of this study, a within group DS comparison after the intervention demonstrated a significant improvement in all anaerobic performance parameters ($p < 0.05$). Only the FI showed a slightly higher average value when compared to baseline. The SK group improved significantly in Peak power output (PPO), Relative peak power output (RPO), and Total RPM when compared to the pretest baseline data ($p<0.05$). However, when all anaerobic performance parameters were compared immediately after intervention, there was no statistically significant difference between the two approaches. We conclude that, in amateur cyclists, warming up with either DS or SK has immediate benefits that result in higher anaerobic performance. As a result, cyclists may consider using the DS or SK as a warm-up mode before a short cycling race.

**Keywords:** Anaerobic performance, Dynamic stretching, Wingate test, Suryanamaskar yoga, Warm up

## 1. Introduction

In sports, it is well established that a proper warm-up can help increase the body's potential for competitive movement and reduce injuries. Warming up before a bike race helps athletes achieve the most efficient use of their bodies. Bicycle racing is a high-speed sprint sport with its main source of energy coming from the anaerobic system, so cyclists with good anaerobic performance can generate a high sprint speed. Therefore, before a race, athletes need to prepare their bodies with exercise for high-speed cycling to be effective [1].

There are many different warm-up methods for athletes to choose from when they are preparing their bodies for competition. In most cases, cyclists use dynamic stretching (DS) prior to training or competitions. It has a movement pattern of the limbs that is similar to those being used in sports. Therefore, it helps stimulate the muscles that are about to be fully functional and increase physical potential in relation to sport [2,3].

DS is a type of active warm-up exercise with large amplitude movements, where joints and muscles go through a full range of motion [4]. Moreover, DS mimics the movement of the activity or sport that the athletes are about to perform. Previous studies have reported that DS training improves physical performance in a number of ways. Participants that had DS training for a period of time improved their lower back and hamstring flexibility, as well as their shoulder and hip joint range of motion [5,6]. It was also reported that after DS training, participants performed better on measures of explosive sports skills such as sprint speed and vertical jumping [7,8].

Although there is a fair amount of research on the effect of DS on physical performance, research studies on the immediate effect of DS warm-up on variables in anaerobic performance as assessed by the Wingate test are lacking. Only one study, by Bradley J. Kendall, reported that DS stretching in healthy subjects had no effect on anaerobic performance as measured using the Wingate test [9]. This study, however, was conducted on average, healthy persons of various ages. Moreover, the sample size used in this study is small. Therefore, further studies are needed to explain the effect of DS on anaerobic performance in young athletic adults who are training. Despite the advantages of DS on physical performance, it does have some disadvantages as well. The risk of injury is increased during dynamic stretching [4]. It can cause torn or sprain muscles as it is fast-moving over a wide range of motions.

Suryanamaskar Yoga (SK) is a mode of active stretching exercise modified from Yoga postures where the practitioner consciously and slowly controls the movement of the body parts in certain positions. Most body postures of SK target on leg and trunk muscles, which are the primary muscles used in cycling [10-13]. These muscles work alternately between concentric and eccentric contractions as they transition from one asana to the next. It stretches up to 97 percent of the muscles in the body [5,6]. In SK movements, the torso muscles, in addition to alternating concentric eccentric functions, also have a role in core stabilization. This is very important while performing leg movements when cycling at high speeds. Therefore, SK warming can be another way to get the body ready for cycling, especially at high speeds.

A previous study investigated the effects of SK training in healthy young individuals [14]. This study stated and found that the SK training improves explosive power as measure by vertical jump. There are also other studies on the effects of SK training in athletes by Elumalai S and Manna et al [15-16]. In the study by Elumalai S, it was found that SK training improved upper and lower body explosive power although there was no significant difference when compared with the traditional warm up group investigated SK training volleyball players. Their results stated that the SK training improved upper and lower body explosive power although there was no significant difference when compared with the traditional warm up group. In the latter Manna et al investigated the effect of SK and DS training on enhancing bowling speed in cricket players. After the warm-up protocol, the effect of SK stretching has shown a strong positive significant effect on bowling speed when compared to the baseline values. However, no significant difference was found after looking at the two groups.

In cycling, the Wingate test is an interesting alternative to the anaerobic performance test since the key muscles tested are the leg muscles, which perform the same activity as those used in cycling races. The Wingate test reveals peak power, average power, fatigue index, and spinning speed, all of which are important aspects of anaerobic performance.

Since the SK involves almost the whole-body muscles which are used during speed cycling and its movements are relatively slower with high concentration during the practice than DS, it may be a safe and effective mode of warm-up exercise for the cyclists. However, no research has been done on its effects as compared to the DS. Therefore, the present study aimed to investigate the immediate effects of SK warm-up on the components of anaerobic performance from the Wingate test compared to the DS warm-up, the standard warm-up method used by most athletes before the races.

## 2. Materials and methods

### *2.1 Study design*

This study was designed to determine the acute effects of dynamic stretching and Suryanamaskar yoga using Wingate Anaerobic Test (WAnT) performance. Participants used a Monark 894E Peak cycle ergometer to complete the Wingate test. This study used the Monark Anaerobic Test which is a unique anaerobic test software (ATS software) package (Certifications: EU directive 93/42/EU Class IIa from Vansbro, Sweden). The test was performed on a Monark Ergomedic 894E cycle. Measured variables were peak power output, mean power output, the fatigue index (FI) and revolutions per min.

### *2.2 Participants*

Participants were healthy male amateur cyclists, who were 20-24 years old, had body mass index values (BMI) between 18.5-22.9 kg/m², regularly exercised at least three days per week, and had been cycling for less than a year. Individuals were excluded if they were professional cyclists, had a history of cardiovascular or respiratory diseases, had musculoskeletal problems or had surgery within the last year (history of surgery). The sample size was determined by considering the relative mean power output (RMP) values from the previous study by Gipson et al [17]. According to the calculations, each group included 30 participants, for a total of two groups. As a result, a total of 60 participants were recruited for the study.

A total of 60 participants were screened and randomly assigned to one of two groups, DS and SK, using block randomization (block size = 4). Written consent from each participant was obtained prior to the start of the study after the participants were informed of possible risks of the experiment.

*2.3 Procedures*

The research was carried out at the Division of Sports Science, Faculty of Sciences of Udon Thani Rajabhat University. Participants visited the laboratory three times for data collection. On the first visit, participants were given detailed information concerning the procedures involved. The experimental sessions commenced a week later. On the second visit, participants completed a medical history questionnaire and the relevant pre-screening procedures to assure safe testing. their completed preliminary health evaluation and physical activity readiness questionnaire (PAR-Q) questionnaires, allowed us to determine that all of the participants were healthy and free from any cardiovascular or neuromuscular irregularities. Following that, the Anaerobic Wingate Test was used to determine their anaerobic capacity as pretest baseline data.

On the third visit, the participants returned to the laboratory after 72 h of rest. The participants' health was first examined by taking their pulse, blood pressure, and filling out a test readiness questionnaire. Initially, participants warmed up by performing DS or SK according to their group. All DS and SK warm-up exercises were supervised by an experienced instructor and administered individually. Each warm-up protocol lasted for 12 minutes. A post-warm up Anaerobic Wingate Test was then performed once they had finished (Figure 1).

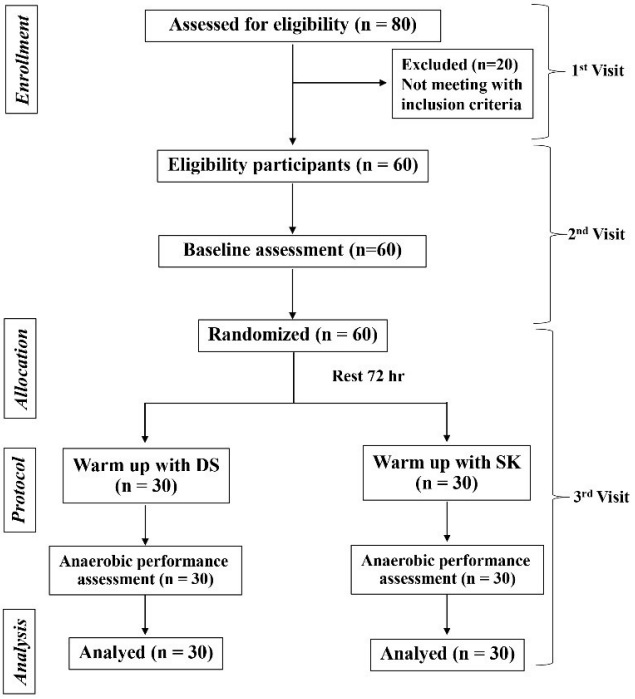


**Figure 1** Flow diagram of the participants through each stage of study.

*2.3.1 Dynamic stretching (DS)*

The participants did nine exercises based on the muscle groups engaged in cycling at a constant, controlled pace throughout the range of motion. DS exercises were performed in the following order front swing, side cross swings, plank walk-outs, lunge torso twists, hug into chest expansion, march and reach, arm push-back, backfist flings and front leg raise toe tap. Each exercise was performed three times, with each set consisting of 20 repetitions. Each set was separated by a two-minute rest break. This DS protocol was developed based on by Leon et al. [18].

*2.3.2 Suryanamaskar yoga (SK)*

SK was performed by the participants in such a way that all 12 postures were cycled through eight times. A practice session consisted of the following: 1) Prayer pose (Pranamasana), 2) Raised arms pose (Hastauttanasana),

3) Hand to foot pose (Hasta Padasana), 4) Equestrian pose (Ashwa Sanchalanasana), 5) Mountain pose (Parvatasana), 6) Salute with eight parts/points (Ashtanga Namaskara), 7) Cobra pose (Bhujangasana), 8) Mountain pose (Parvatasana), 9) Equestrian posture (Ashwa Sanchalanasana), 10) Hand to foot pose (Padahastasana), 11) Raised arms pose (Hastauttanasana), and 12) Salutation pose (Pranamasana). All participants were put through a rhythmic routine that began with an upright standing position and progressed through alternate forward and backward bending movements interspersed with movements using all four limbs before finishing with an erect standing position. Participants must breathe deeply and regularly while performing, and their movements must flow in time with their breath.

*2.3.3 Wingate anaerobic test (WAnT)*

The participants first warmed up on a cycle ergometer (Monark 894E, Stockholm, Sweden) for two minutes at 80 rpm with no resistance. After warming up, the participants performed a 30 second WAnT with a 75 g/kg body weight load. The participants were verbally encouraged to maintain as high a pedalling rate as possible throughout the 30 second test. The Wingate test results were transferred to a computer via Monark Anaerobic Test Software. Peak power output (PPO), mean power output (MPO), FI and revolutions per minute were calculated by this software.

WAnT were performed using a friction belt cycle ergometer (Monark© 874E, Varberg, Sweden). At the start of each testing session, the power meter was calibrated according to the manufacturer's instructions. The cycle ergometer's saddle and handlebar settings were individually modified to suit each participant's body size.

All participants were advised to warm-up for two minutes on a cycle ergometer with no resistance load, pedalling at an intensity of 80 rpm. Following the warm-up period, the cycle ergometer was programmed for a 30-s test duration against resistance equal to 75 g/kg of the cyclist's body weight. The participants then completed an "all-out" 30-sec effort with verbal encouragement. After finishing the trial, participants completed an active cool-down during a two-minute period without resistance. The Wingate test results were transferred to a computer via Monark Anaerobic Test Software. Four anaerobic performance indexes were calculated: PPO, MPO, FI and revolutions per minute. PPO corresponds to the maximum five-second mean power in the test, and the FI was the degree (percentage) of power drop-off during the 30 sec WAnT. Power units can be in Watts or kg/min. The Lowest Power is the anaerobic power for the 5 sec interval that was found to be the lowest of the six intervals. [19].

A minimum of 24 h rest was required between tests. Participants were advised to sleep at least eight hours before the testing day. They also were asked to keep the same diet during test days, and to refrain from food and energy drink intake at least four hours prior to testing. Additionally, they were also asked to avoid strenuous exercise for at least one day prior to testing. Testing took place at the same time each day and all testing sessions were separated by at least 72 h to provide participants with sufficient time to recover.

*2.4 Statistical analysis*

The data was processed using IBM SPSS Version 22.0 software for Windows (Microsoft Corporation, USA). Descriptive statistics were used to describe baseline demographics and findings of the study. The Shapiro-Wilk test was employed to ensure a normal distribution of the data. The participants' physical characteristics were weight, age, height, BMI, and PPO, relative peak power output (RPO), FI and revolutions per minute over 30 sec (revolution per minute (RPM) 30 sec). The results are reported as mean, and standard deviation values. The Wilcoxon Signed Rank test was used to examine the differences within groups, and the outcome variables following DS and SK were compared to baseline. The Mann-Whitney U test was used to compare the differences in outcome variables between the two groups.

## 3. Results

The participant's demographic data and health status were expressed as mean and standard deviation are shown in (Table1). There were sixty participants in the DS and SK groups, with average ages (mean ± standard deviation (SD)) of 20.60 ± 0.62 and 20.30 ± 0.53 years, respectively. In the DS group, there were average weight, height, and body mass index values of 63.20 ± 6.00 kg., 1.72 ± 0.53 m, 21.31 ± 1.40 kg/m$^2$, respectively. In the SK group, the average weight, height, and body mass index were of 64.03 ± 6.84 kg., 1.72 ± 0.65 m, 21.59 ± 1.64 kg/m$^2$, respectively. Participant's demographic data thus did not differ between the two groups.

Table 2 shows non-statistical significance ($p > 0.05$) of the baselines (pre-test) of all parameters when comparing between 2 groups. When comparing within a group, DS showed significant improvement ($p < 0.01$) in almost all parameters, except RMP and FI, while SK showed significant improvement in only PPO ($p < 0.05$).

*3.1 Anaerobic performance*

A within group DS comparison revealed a significant increase in PPO, RPO, MPO and RMP at $p < 0.05$ when compared to baseline data as shown in Table 3. SK group, a significant increase was found in PPO, MPO but did not change MPO and RMP significantly as shown in Table 4. In between group comparisons, there were no significant differences between DS and SK groups in baseline and post-test data (Table 2 and table 5). Although the post-PPO was slightly higher in the SK when compared to DS group, statistical analyses were not significantly different but just presented a trend ($p = 0.069$).

*3.2 Fatigue index (FI)*

The values of FI showed no significant change between groups in both baseline and post-test data (Table 2 and table 5). No significant differences were observed in DS compared to the SK group in both baseline and post-test data as shown in Table 5. In the SK group, no significant difference was observed between baseline and post-test data. It was also observed that FI in DS group at post-test showed a significant higher when compared to baseline (0.021), which indicates a weaker state of anaerobic capacity, or lower tolerance to lactate (Table 3).

*3.3 Total RPM 30 sec*

The RPM for 30 sec taken in five second intervals in the Wingate test showed significant improvement within the DS group at Time 0-5 sec, Time 5-10 sec, Time 10-15 sec, Time 25-30 sec and Total RPM at $p < 0.05$ (Table 3). In the SK group, improvement was found Time 0-5 sec, Time 5-10 sec and Total RPM at $p < 0.05$ (Table 4). A between group comparison showed no significant differences both before and after the intervention (Table 5) indicating an equally improvement of Total RPM for both groups after the intervention.

**Table 1** Participant's demographic data and health status.

| Characteristics | DS (n=30) | SK (n=30) | Diff. | *p*-value |
|---|---|---|---|---|
| Age (year) | 20.60 ± 0.62 | 20.30 ± 0.53 | 0.30 | 0.50 |
| Weight (kg) | 63.20 ± 6.00 | 64.03 ± 6.84 | -0.83 | 0.61 |
| Height (m) | 1.72 ± 0.53 | 1.72 ± 0.65 | 0.00 | 0.98 |
| BMI (kg/m²) | 21.31 ± 1.40 | 21.59 ± 1.64 | -0.28 | 0.47 |

Data are mean ± SD, DS, Dynamic stretching group, SK, Suryanamaskar yoga group.

**Table 2** Comparison of baseline (pre-test) between DS and SK.

| Parameter | Group | N | Mean rank | Sum of ranks | U | *p*-value |
|---|---|---|---|---|---|---|
| PPO (Watt) | DS | 30 | 31.63 | 949.00 | 416.00 | 0.615 |
| | SK | 30 | 29.37 | 881.00 | | |
| RPO (Watt/kg) | DS | 30 | 29.92 | 897.50 | 432.50 | 0.796 |
| | SK | 30 | 31.08 | 932.50 | | |
| MPO (Watt) | DS | 30 | 32.03 | 961.00 | 404.00 | 0.496 |
| | SK | 30 | 28.97 | 869.00 | | |
| RMP (Watt/kg) | DS | 30 | 29.62 | 888.50 | 423.50 | 0.695 |
| | SK | 30 | 31.38 | 941.50 | | |
| FI (%) | DS | 30 | 29.23 | 877.00 | 412.00 | 0.574 |
| | SK | 30 | 31.77 | 953.00 | | |
| RPM 30 sec | | | | | | |
| Time 0-5 sec | DS | 30 | 31.95 | 958.50 | 406.50 | 0.520 |
| | SK | 30 | 29.05 | 871.50 | | |
| Time 5-10 sec | DS | 30 | 30.28 | 908.50 | 443.50 | 0.923 |
| | SK | 30 | 30.72 | 921.50 | | |
| Time 10-15 sec | DS | 30 | 28.82 | 864.50 | 399.50 | 0.455 |
| | SK | 30 | 32.18 | 965.50 | | |
| Time 15-20 sec | DS | 30 | 29.13 | 874.00 | 409.00 | 0.544 |
| | SK | 30 | 31.87 | 956.00 | | |

**Table 2** (continued) Comparison of baseline (pre-test) between DS and SK.

| Parameter | Group | N | Mean rank | Sum of ranks | U | *p*-value |
|---|---|---|---|---|---|---|
| RPM 30 sec | | | | | | |
| | | 30 | 30.35 | 910.50 | | |
| Time 25-30 sec | DS | 30 | 30.47 | 914.00 | 449.00 | 0.988 |
| | SK | 30 | 30.53 | 916.00 | | |
| Total RPM | DS | 30 | 30.58 | 917.50 | 447.50 | 0.971 |
| | SK | 30 | 30.42 | 912.50 | | |

Note: PPO = peak power output, RPO = relative peak power output, MPO = mean power output, RMP = relative mean power output, FI = fatigues index; *p*-value < 0.05.

**Table 3** Comparison between pre-test vs post-tests in DS group.

| Parameter | Group | N | Mean rank | Sum of ranks | Z | *p*-value |
|---|---|---|---|---|---|---|
| PPO (Watt) | Negative Value | 5 | 12.80 | 64.00 | -3.466 | 0.001*** |
| | Positive Value | 25 | 16.40 | 401.00 | | |
| | Equal | 0 | | | | |
| RPO (Watt/kg) | Negative Value | 5 | 11.60 | 58.00 | -3.589 | 0.001*** |
| | Positive Value | 25 | 16.28 | 407.00 | | |
| | Equal | 0 | | | | |
| MPO (Watt) | Negative Value | 6 | 11.83 | 71.00 | -3.322 | 0.001*** |
| | Positive Value | 24 | 16.42 | 394.00 | | |
| | Equal | 0 | | | | |
| RMP (Watt/kg) | Negative Value | 7 | 10.93 | 76.50 | -3.209 | 0.001*** |
| | Positive Value | 23 | 16.89 | 388.50 | | |
| | Equal | 0 | | | | |
| FI (%) | Negative Value | 8 | 15.00 | 120.00 | -2.314 | 0.021* |
| | Positive Value | 22 | 15.68 | 345.00 | | |
| | Equal | 0 | | | | |
| RPM 30 sec | | | | | | |
| Time 0-5 sec | Negative Value | 2 | 10.50 | 21.00 | -4.352 | 0.001*** |
| | Positive Value | 28 | 15.86 | 444.00 | | |
| | Equal | 0 | | | | |
| Time 5-10 sec | Negative Value | 3 | 4.50 | 13.50 | -4.507 | 0.001*** |
| | Positive Value | 27 | 16.72 | 451.50 | | |
| | Equal | 0 | | | | |
| Time 10-15 sec | Negative Value | 9 | 10.06 | 90.50 | -2.922 | 0.003** |
| | Positive Value | 21 | 17.83 | 374.50 | | |
| | Equal | 0 | | | | |
| Time 15-20 sec | Negative Value | 14 | 15.25 | 213.50 | -0.239 | 0.811 |
| | Positive Value | 14 | 13.75 | 192.50 | | |
| | Equal | 2 | | | | |
| Time 20-25 sec | Negative Value | 19 | 13.87 | 263.50 | -1.793 | 0.073 |
| | Positive Value | 8 | 14.31 | 114.50 | | |
| | Equal | 3 | | | | |
| Time 25-30 sec | Negative Value | 21 | 15.57 | 327.00 | -2.371 | 0.018** |
| | Positive Value | 8 | 13.50 | 108.00 | | |
| | Equal | 1 | | | | |
| Total RPM | Negative Value | 6 | 7.67 | 46.00 | -3.837 | 0.001*** |
| | Positive Value | 24 | 17.46 | 419.00 | | |
| | Equal | 0 | | | | |

Note: PPO = peak power output, RPO = relative peak power output, MPO = mean power output, RMP = relative mean power output, FI = fatigues index; *$p$-value < 0.05. **$p$ <0.01, ***$p$ < 0.001.

**Table 4** Comparison between pre-test vs post-tests in SK group.

| Parameter | Group | N | Mean rank | Sum of ranks | Z | *p*-value |
|---|---|---|---|---|---|---|
| PPO (Watt) | Negative Value | 7 | 11.71 | 82.00 | -3.096 | 0.002** |
| | Positive Value | 23 | 16.65 | 383.00 | | |
| | Equal | 0 | | | | |
| RPO (Watt/kg) | Negative Value | 7 | 11.29 | 79.00 | -3.159 | 0.002** |
| | Positive Value | 23 | 16.78 | 386.00 | | |
| | Equal | 0 | | | | |
| MPO (Watt) | Negative Value | 12 | 12.92 | 155.00 | -1.594 | 0.111 |
| | Positive Value | 18 | 17.22 | 310.00 | | |
| | Equal | 0 | | | | |
| RMP (Watt/kg) | Negative Value | 12 | 12.96 | 155.50 | -1.584 | 0.113 |
| | Positive Value | 18 | 17.19 | 309.50 | | |
| | Equal | 0 | | | | |
| FI (%) | Negative Value | 17 | 15.53 | 264.00 | -0.648 | 0.517 |
| | Positive Value | 13 | 15.46 | 201.00 | | |
| | Equal | 0 | | | | |
| RPM 30 second | | | | | | |
| Time 0-5 sec | Negative Value | 4 | 5.25 | 21.00 | -4.146 | 0.001*** |
| | Positive Value | 24 | 16.04 | 385.00 | | |
| | Equal | 2 | | | | |
| Time 5-10 sec | Negative Value | 6 | 9.75 | 58.50 | -3.138 | 0.002** |
| | Positive Value | 21 | 15.21 | 319.50 | | |
| | Equal | 3 | | | | |
| Time 10-15 sec | Negative Value | 15 | 15.00 | 225.00 | -0.867 | 0.386 |
| | Positive Value | 12 | 12.75 | 153.00 | | |
| | Equal | 3 | | | | |
| Time 15-20 sec | Negative Value | 14 | 14.25 | 199.50 | -0.612 | 0.541 |
| | Positive Value | 12 | 12.63 | 151.50 | | |
| | Equal | 4 | | | | |
| Time 20-25 sec | Negative Value | 16 | 16.72 | 267.50 | -1.472 | 0.141 |
| | Positive Value | 12 | 11.54 | 138.50 | | |
| | Equal | 2 | | | | |
| Time 25-30 sec | Negative Value | 16 | 16.09 | 257.50 | -1.242 | 0.214 |
| | Positive Value | 12 | 12.38 | 148.50 | | |
| | Equal | 2 | | | | |
| Total RPM | Negative Value | 9 | 11.83 | 106.50 | -2.401 | 0.016* |
| | Positive Value | 20 | 16.43 | 328.50 | | |
| | Equal | 1 | | | | |

Note: PPO = peak power output, RPO = relative peak power output, MPO = mean power output, RMP = relative mean power output, FI = fatigues index; * *p*-value < 0.05. ** *p* <0.01, *** *p* < 0.001.

**Table 5** Comparison of post-test between DS and SK.

| Parameter | Group | N | Mean rank | Sum of ranks | U | *p*-value |
|---|---|---|---|---|---|---|
| PPO (Watt) | DS | 30 | 34.60 | 1038.00 | 327.00 | 0.069 |
| | SK | 30 | 26.40 | 792.00 | | |
| RPO (Watt/kg) | DS | 30 | 33.63 | 1009.00 | 356.00 | 0.165 |
| | SK | 30 | 27.37 | 821.00 | | |
| MPO (Watt) | DS | 30 | 33.30 | 999.00 | 366.00 | 0.214 |
| | SK | 30 | 27.70 | 831.00 | | |
| RMP (Watt/kg) | DS | 30 | 32.88 | 896.50 | 378.50 | 0.290 |
| | SK | 30 | 28.12 | 843.50 | | |
| FI (%) | DS | 30 | 33.83 | 1051.00 | 350.00 | 0.139 |
| | SK | 30 | 27.17 | 815.00 | | |
| RPM 30 second | | | | | 367.00 | 0.219 |
| Time 0-5 sec | DS | 30 | 33.27 | 998.00 | | |
| | SK | 30 | 27.73 | 832.00 | | |
| Time 5-10 sec | DS | 30 | 35.58 | 1067.50 | 297.50 | 0.204 |
| | SK | 30 | 25.42 | 762.50 | | |

**Table 5** (continued) Comparison of post-test between DS and SK.

| Parameter | Group | N | Mean rank | Sum of ranks | U | *p*-value |
|---|---|---|---|---|---|---|
| RPM 30 second | | | | | | |
| Time 10-15 sec | DS | 30 | 35.18 | 1055.50 | 309.50 | 0.068 |
| | SK | 30 | 25.82 | 774.50 | | |
| Time 15-20 sec | DS | 30 | 31.37 | 941.00 | 424.00 | 0.700 |
| | SK | 30 | 29.83 | 889.00 | | |
| Time 20-25 sec | DS | 30 | 31.17 | 935.00 | 430.00 | 0.767 |
| | SK | 30 | 29.83 | 895.00 | | |
| Time 25-30 sec | DS | 30 | 29.42 | 882.50 | 417.50 | 0.630 |
| | SK | 30 | 31.58 | 947.50 | | |
| Total RPM | DS | 30 | 33.85 | 1015.50 | 349.50 | 0.137 |
| | SK | 30 | 27.15 | 814.50 | | |

Note: PPO = peak power output, RPO = relative peak power output, MPO = mean power output, RMP = relative mean power output, FI = fatigues index; $^{*}p$-value < 0.05.

## 4. Discussion

The present study aimed to compare the acute effects of DS and SK on amateur cyclists' anaerobic power, anaerobic capacity, fatigue index, and revolutions per minute. We found that both DS and SK have immediate effects that result in higher anaerobic performance. Warming up with DS and SK, on the other hand, yields no statistically significant difference in terms of improving the anaerobic performance of amateur bikers.

After warming up, PPO, RPO, and Total RPM increased significantly in the SK group. This data shows that after intervention, the participants in this group improved their anaerobic performance. Furthermore, the fact that the Fatigue index FI value does not change after warming up indicates that warming up with SK does not result in a decrease in muscle tolerance to lactate, which means that warming up with SK does not cause muscle fatigue to increase during the WAnT (Table 4).

Previous research on SK has primarily focused on its impact on flexibility, with studies examining both immediate and post-training outcomes [20-24]. Some previous research studies investigated its effect on muscular strength and the cardiovascular system. [20,21]. The current study is the first to report the effects of SK on anaerobic performance, focusing on the immediate effects of warming up with SK. The results clearly demonstrated that the participants showed superior RPO values and more leg cycles in the first 10 seconds of spinning after warming up with SK. Suryanamaskar yoga stretching uses active muscular effort to lengthen muscles. SK movements are mixed with alternate muscle expansion and contraction, followed by a few seconds of holding a yoga pose. It is vital to breathe slowly and deeply throughout the movements [22,23]. With these types of movement, muscle stiffness is reduced, neurotransmission is improved, and the power-to-acceleration connection is improved. Disrupting stable connections between actin and myosin during SK may also reduce muscle stiffness and have an impact on short-term anaerobic performance [3,24-26]. According to Earp et al [27], muscle contraction speed and the ability to perform power exercises are both improved in line with muscle fiber elongation. Thus, the improvement in the sprinting tests measured using the Wingate protocol herein could be attributed to an improvement in muscle fiber length. Moreover, in SK, the breathing patterns are respiratory warm-ups that might contribute to anaerobic performance. According to a study by Özdal M., respiratory muscle warm-up may positively increase anaerobic power due to faster attainment of peak power. [28]

As shown in Table 3, the participants in the DS group showed greater anaerobic performance when compared to baseline. Almost all anaerobic performance parameters in this group improved significantly after warming up with DS. Only the FI showed a slightly higher average value when compared to baseline, indicating that muscles had lower lactate tolerance. It could be explained that DS technique demands movement speed, has bouncing characteristics, and lacks pauses in the last steps of movements These movement characteristics are similar to those used in sprint cycling, leading to proper movement of joints [29], that bring about power [3, 30] and sprinting ability [1,31]. This helps their muscles to generate more power with cycling movement and resulting in higher cycling speeds.

In between group comparisons, there were no significant differences in all parameters between DS and SK groups in post-test data. The improvement of PPO, RPO and Total RPM in both groups showed the improvement of anaerobic performance of the participants in both groups. The higher anaerobic capacity of cyclists immediate after warming up with DS or SK could have been a result of their ability to spontaneously generate power. Additionally, the increase in body temperature after warming up also helps in muscle contraction and stimulation of the force nervous system. This helps in nervous stimulation and prevents stimulation of unneeded muscles as well as resulting in higher force and power [3,29,32]. The result of the present study of the acute effect of DS on anaerobic performance are in agreement with Yamaguchi et al., who found that dynamic stretching significantly heightened power output compared to a control group [33]. Similarly, Franco et al. reported that the DS technique

contributed to a higher time to reach the peak power output (TP) scores in the Wingate anaerobic test [5,34]. Previous studies have shown the effects of yoga training on helping to enhance the aerobic performance of different groups of volunteers [35]. Our study is the first to report an immediate improvement in anaerobic performance following SK warming up, as demonstrated by an increase in relative peak power output. Although there was no statistically significant difference in RPO between the DS and SK groups, participants in the DS group tended to obtain higher RPO levels than those in the SK group following the intervention ($11.60 \pm 1.85$ and $10.80 \pm 1.35$, respectively) [36].

Based on our findings, warming up with SK or DS can improve anaerobic performance of amateur cyclists. The fundamental mechanism of this improvement is reduced muscle stiffness, altered length-tension relationships, and improved neuronal variables. However, when taking into account the risk of muscle damage from the quick movements of DS strength, warming up with SK is an alternative that can also boost anaerobic performance.

The study's limitation is that it only included male amateur cyclists who volunteered to take part in the study. Further research into the effect of SK yoga on the Wingate anaerobic test in a larger population and elite cyclists is still required. Further study is necessary to evaluate the effect of SK on the WAnT.

## 5. Conclusion

Warming up with either SK or DS can greatly enhance anaerobic performance in amateur cyclists, and the results are comparable for both techniques.

## 6. Ethical approval

The study protocol was approved by the Center for Ethics in Human Research, Khon Kaen University, Thailand (HE622109/2562).

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