The effects of seat tube angle on the metabolic cost during cycling at low intensity workload

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Abstract

The effects of seat tube angle (STA) on the cycling performance at low intensity were investigated in terms of metabolic cost. Oxygen consumption (VO\textsubscript{2}), heart rate (HR), ventilation (VE) were measured during cycling at each of three STA (80°, 60°, 40°) and at constant 60° upper body angle using a custom made steady-state ergometer. 12 male untrained students (age 24.5 ± 1.6 years) were recruited and submaximal cycling tests (work load: 35% of individual peak power, cadence: 60rpm, duration: 30min) were performed. Measured mean VO\textsubscript{2} were 24.6 ± 2.8, 25.2 ± 2.9 and 24.8 ± 2.5 ml/min*kg and mean heart rates were 140.7 ± 10, 132.8 ± 8.8 and 131.7 ± 10.1 beat/min at 80°, 60° and 40° STA, respectively. There was no significant difference on the oxygen consumption but the mean heart rate at 60° and 40° STA was significantly lower than at 80° STA. In conclusion, riding a bicycle at shallow STA is as cost efficient as at steep STA and is better in terms of heart rate which is evaluated to be more suitable postures for casual cycling.

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Keywords: Cycling performance; seat tube angle; metabolic cost.

1. Introduction

People tend to ride a bicycle at a low saddle height because they feel more stable when their feet can touch the ground. However, many researchers recommend to adjust the saddle distance to about 107% of inseam length [1], to 96–100% of trochanteric height [2], or such that knee flexion is about 25°–30° when

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the pedal is located at the bottom dead center [3]. Previous studies on effect of STA on cycling performance were done mostly on restricted STA variation. Road racing cyclists prefer a STA between 72° and 76°, whereas triathletes prefer a STA between 70° and 78° [9]. Since the studies are on the professional cyclist for enhancing performance, further investigation on the nonprofessional cyclist was required. When STA is adjusted to a shallow angle, appropriate saddle distance can be achieved while the saddle height from the ground is kept low (Figure 1). This facilitates get on and get off the bicycle and prevents knee injury by maintaining proper distance to the pedal. But if the cycling position is changed to shallower STA, trunk-thigh angle is decreased, thereby affecting joint range of motion, length of muscles, muscle activity during cycling. However, there are few studies on the effect of STA on postures used in casual and low intensity cycling in the city. Therefore, in this study, metabolic cost during casual cycling at low work load and wide range of STA from 40° to 80° was evaluated.

![Fig. 1. Seated posture on bicycle with shallow STA](image)

2. Method

Oxygen consumption was measured from 12 untrained healthy male adults (age: 24.5 ± 1.6 years, height: 175 ± 4.8cm, weight: 70 ± 7.8kg) during cycling with STA of 80°, 60°, and 40°. The angle of the upper body was held constant at 60°. Subjects were briefed regarding their health and signed the written consent form prior to the experiment. For the experiment, a custom made steady-state ergometer was used to change the posture and the wireless gas analysis system K4B2 was used to measure oxygen consumption (VO2), ventilation (VE), respiratory exchange ratio (R), and heart rate (HR). Work load for each subject was set to 35% of individual peak power measured at a pedal speed of 60 rpm. The subject was instructed to pedal at 60rpm for 30 minutes at randomly selected posture. Subject was forbidden from eating and drinking coffee 2 hours prior to the experiment. The experiment was performed for each posture (80°, 60°, and 40°) on different days but at same time of the day.
3. Results

VO₂, HR, and R values were analyzed for final 5 minute interval of total 30 minute experiment time, during which subjects have accumulated fatigue. Table 1 shows values of the measured data. Unpaired t-tests were performed to test the difference between 80° and 60°, between 60° and 40°, and between 80° and 40°. From the analysis, average VO₂ was lowest when STA was 80° (24.6 ml/min*kg) and highest when STA was 60° (25.2 ml/min*kg), but there was no statistically significant difference. However, average HR per minute were 132.8 and 131.7 at STA of 60° and 40° respectively, which were significantly lower than 140.7 at STA of 80° (p < 0.01).

Table 1. Analysis of respiratory gas with change in STA (upper body angle held constant at 60°).

<table>
<thead>
<tr>
<th>Seat tube angle</th>
<th>STA 80°</th>
<th>STA 60°</th>
<th>STA 40°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation per minute (l/min)</td>
<td>45.0±7.3</td>
<td>43.6±4.8</td>
<td>43.2±6.3</td>
</tr>
<tr>
<td>Oxygen consumption per minute (ml/min*kg)</td>
<td>24.6±2.8</td>
<td>25.2±2.9</td>
<td>24.8±2.5</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>140.7±10.0</td>
<td>132.8±8.8</td>
<td>131.7±10.1</td>
</tr>
<tr>
<td>Respiratory exchange ratio (R)</td>
<td>0.98±0.07</td>
<td>0.97±0.07</td>
<td>0.96±0.05</td>
</tr>
</tbody>
</table>

![Fig. 2. Cycling postures with varied STA (STA 80° (left); 60° (center); 40° (right); upper body angle was held constant at 60°)](image)

![Fig. 3. Comparison of VO₂ and HR with change in STA (*p < 0.05, **p < 0.01, ***p < 0.001)](image)
Price reported that VO2 was lower for a steeper STA after experimenting at STA of 68°, 74°, and 80° [4]. Heil showed that there was significant increase in VO2 and HR at shallow STA after performing experiment at 73% of work load of VO2max and 69°, 76°, 83° and 90° STA [8]. These studies conclude that metabolic cost becomes more efficient at steeper STA because the posture is aerodynamically favorable. However, Heil’s other study reported that cycling at shallow STA with shallow upper body angle (10°) is an inefficient posture due to high VO2 and HR [7]. But STA changes did not affect VO2 when upper body angle was 30°. On the contrary, a cycling posture that shows low VO2 corresponded to the posture preferred by the subjects [5]. This signifies that at casual cycling posture in which the upper body is upright, HR and VO2 do not significantly depend on STA. Instead, changing STA to accommodate familiar or trained posture for the user leads to better cycling performance in casual cycling. The finding in this study that there is no statistically significant difference in metabolic cost with respect to change in STA is consistent with previous studies. Also, HR increases at steeper STA due to increased body weight load on the arms, which is in agreement with previous studies [6] [7].

4. Conclusion

The effect of varied STA (80°, 60°, and 40°) on human body during cycling was investigated in terms of metabolic cost. When experiments were performed at low intensity to simulate casual cycling, the STA did not affect on VO2. But the HR at 60° and 40° STA were significantly lower than the HR at 80° STA, and 60° and 40° STA are evaluated to be more suitable postures for casual cycling. STA below 60° allows for maintaining appropriate saddle distance while allowing the feet to touch the ground, thereby ensuring safety and accessibility.

References