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Original Article

Relative variances of the cadence frequency of cycling under two differential saddle heights

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Abstract. [Purpose] Bicycle saddle height is a critical factor for cycling performance and injury prevention. The present study compared the variance in cadence frequency after exercise fatigue between saddle heights with 25° and 35° knee flexion. [Methods] Two saddle heights, which were determined by setting the pedal at the bottom dead point with 35° and 25° knee flexion, were used for testing. The relative variances of the cadence frequency were calculated at the end of a 5-minute warm-up period and 5 minutes after inducing exercise fatigue. Comparison of the absolute values of the cadence frequency under the two saddle heights revealed a difference in pedaling efficiency. [Results] Five minutes after inducing exercise fatigue, the relative variances of the cadence frequency for the saddle height with 35° knee flexion was higher than that for the saddle height with 25° knee flexion. [Conclusion] The current finding demonstrated that a saddle height with 25° knee flexion is more appropriate for cyclists than a saddle height with 35° knee flexion.

Key words: Saddle height, Pedaling efficiency, Exercise

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INTRODUCTION

Sports injuries in cyclists are frequently caused by an abnormal cycling position in which a repetitive motion occurs with a relatively fixed knee position and insufficient muscular endurance in the lower limbs[1)]. Bicycle saddle height is a critical factor for cycling performance and injury prevention[2)]. An incorrectly set saddle height can cause a considerable strain on the knees and lead to knee overuse injury[3)]. The knee joint provides power to pedal and drive a bike during cycling; however, knee overuse is a common sports injury[4)]. Therefore, the height of the cyclist's saddle is critical to preventing sports injury.

The height of the cyclist's saddle is also critical for optimizing performance and reducing the risk of knee overuse injury during cycling[5)]. One study indicated that effective prevention of knee injury entails setting the bottom dead point of the pedal at a position[6)], that allows the knee to be flexed between 25° and 35°. Another study recommended that the saddle height permit 25–35° knee flexion and determined that a knee angle closer to 25° than 35° facilitated sports performance and injury prevention[7)].

During cycling, the bike must fit a cyclist as possible, which could have optimal sports performance[8)]. Whether professional or amateur, cyclists seek techniques for improving their cycling performance. The optimal pedaling rhythm is one that maintains the minimum pedaling force requirements to provide bike power. This allows cyclists to use slow-twitch fibers for primary muscle power, and this allows anaerobic capability to be reserved to delay exercise fatigue[9)]. Because cycling exercise is a prolonged physical activity, a stable cycling speed is essential to maintaining the fitness of the cyclist, who must

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compensate for exercise fatigue through riding posture and chaotic pedaling rhythms, thereby affecting individual or team performance[10]. Adequate fitness and muscular endurance are critical to fundamental athletic performance[11, 12], with external factors such as bicycle architecture also affecting performance[13]. Previous studies have frequently explored seat height and demonstrated that inappropriate seat height could affect cycling performance[14, 15]. However, few studies have explored how seat height affects pedaling rhythm. Therefore, our study compared the variance in cadence frequency after exercise fatigue between saddle heights with 25° and 35° knee flexion. The results may elucidate the positive effect of a suitable saddle height for cyclists. The variance in cadence frequency was hypothesized to be less for a saddle height with 25° knee flexion than that for one with 35° knee flexion.

SUBJECTS AND METHODS

This study adopted a crossover design to assess the difference in cadence frequency between the two saddle heights among healthy college students aged older than 20 years. All participants provided informed consent before the study, and the procedure was approved by the Research Ethics Committee of a hospital. The inclusion criteria were a healthy status and cycling experience. The exclusion criteria were a history of lower limb injury, an anterior or lateral cruciate ligament tear, a meniscus lesion or ankle ligament tear, or cardiovascular disease.

The variable in this study was saddle height, which was set at two different heights by setting the pedal at the bottom dead point with 35° or 25° knee flexion, respectively (Fig. 1). The participants were randomly assigned to test each saddle height (i.e., with 25° or 35° knee flexion) for 2 days, with a 2-day rest between testing of the two cycling protocols to avoid muscle fatigue. A cadence bike sensor (Edge 510, Garmin, Olathe, KS, USA) with a heart rate sensor was used, and a 10-grade rating of perceived exertion (RPE) was adopted for assessing exercise fatigue. The heart rate reaching 90% of its predicted maximum and the RPE reaching a grade of 7 were used for judgment of exercise fatigue[16].

The participants were asked to pedal to fatigue in the cycling exercise, and the cadence frequency was recorded from the start of a 5-minute warm-up period until 5 minutes after inducing exercise fatigue. Before the exercise began, the protocol was explained to the participants in detail, alerting them to precautions and informing them of the assessment project. Each participant was allowed to ride a stationary bike and set the saddle height before adjusting the amount of resistance (7 grades) requesting that the participant maintain a cadence frequency of 85 rpm, which is a common training model for cyclists. After the resistance and saddle height were properly adjusted, recording of the cadence frequency was started for the 5-minute warm-up. After exercise fatigue was induced, recoding of the cadence frequency was continued for 5 minutes of exercise fatigue. The cadence frequency of the rider was recorded and analyzed. The relative variance of the cadence frequency was calculated as the current cadence frequency − the set cadence frequency (85 rpm). This equation denotes the pedaling efficiency, which was calculated at the end of the 5-minute warm-up period and 5 minutes after inducing exercise fatigue.

The data obtained were analyzed using the SPSS Version 15 software (SPSS, Inc., Chicago, IL, USA). Descriptive statistics (i.e., mean and standard deviation) of the participants' demographic data were calculated. The Wilcoxon test was used, and the α value was set at 0.05. Comparing the absolute values of cadence frequency under the two conditions with the two saddle heights revealed a difference in pedaling efficiency.

RESULTS

Ten healthy college students (age = 22.5 ± 0.9, weight = 61.3 ± 5.1 kg, and height = 169.3 ± 5.1 cm) were recruited and randomly performed the cycling protocols, which entailed cycling with a saddle height set to allow 25° or 35° knee flexion. The relative variance in cadence frequency denoted the difference between the actual and set cadence frequencies. The set cadence frequency was 85 rpm. Comparison of the variance in cadence frequency for saddle heights with 25° or 35° knee flexion revealed no significant difference after the 5-minute warm-up (Table 1). A significant difference was found using the saddle height with 35° knee flexion after the 5-minute warm-up and 5 minutes after inducing exercise fatigue ($p = 0.001$). Comparing the mean and standard deviation of the cadence frequency after the 5-minute warm-up and 5 minutes after inducing exercise fatigue revealed a significant difference between the saddle heights with 25° and 35° knee flexion ($p = 0.001$).

DISCUSSION

A saddle height with 35° knee flexion means that the cyclist is seated at a lower saddle height, with the knees remaining flexed during peddling. A saddle height with 25° knee flexion means that the cyclist is seated at a higher saddle height, with the knees extending during peddling. A cyclist seated at a saddle height with 35° knee flexion maintains a long quadriceps muscle length. According to the muscular length-tension ratio, when the length of the muscle surpasses its primary length, passive elastic tension in the muscle initiates factors that cause a greater contraction force[17, 18]. However, excess power output causes muscle fatigue during extended periods of cycling. Our results indicated that the saddle height with 35° knee flexion had a relatively high variance in cadence frequency, meaning an increase in chaotic pedaling rhythms. When the knee is almost fully extended, cycling is perceived to be easier and is more effective, indicating that a high saddle height results in reduced muscular work[19]. Peveler et al. found that anaerobic power in a graded exercise protocol was significantly

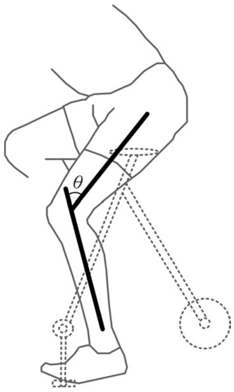

Fig. 1. Saddle height setting (θ is 35° or 25° knee flexion)

Table 1. Absolute values of relative variance of cadence frequency

	Saddle height with 25°knee flexion (n = 10)	Saddle height with 35° knee flexion (n = 10)
5-min warm-up	2.62 ± 1.25	2.53 ± 1.76
5 minutes after inducing exercise fatigue	2.32 ± 1.83	4.21 ± 2.65*+

*p < 0.05, saddle heights with 25° vs. 35° knee flexion
+ p < 0.05, 5-min warm-up vs. 5-min exercise fatigue

lower for a saddle height with 25° knee flexion than for one with 35° knee flexion[7]. In the current study, the current findings supported to the idea that a saddle height with 35° knee flexion would increase power consumption, resulting in an increased relative variance in cadence frequency 5 minutes after inducing exercise fatigue. However, the saddle height with 25° knee flexion exhibited a significantly lower relative variance in cadence frequency than the saddle height with 35° knee flexion. Therefore, cycling with a low saddle height could reduce chaotic pedaling rhythms during exercise fatigue, thus benefiting cycling performance.

An incorrect saddle height can exert considerable strain on the knee joint, resulting in an increase of overuse injuries[20]. Although the current study did not explore the effects of different saddle heights on injury prevention, an experimental study established that a saddle height with 25–35° knee flexion is ideal for injury prevention[21]. However, some studies have recommended a saddle height with 25° knee flexion for injury prevention[6, 20]. An overly low saddle height can cause anterior knee pain from increased compression of the knee joint as the cyclist pushes through the top of the pedal stroke[7]. Holmes et al. thought that low saddle heights had a high risk of knee overcompression when cycling, which could also result in overuse injuries involving cyclists' knee joints[22]. Bini et al. found that increasing saddle height could result in large increases in the index of cyclists' effectiveness[23]. The results of the current study reveal that a saddle height with 25° knee flexion had a lower relative variance in cadence frequency, and it was presumed that high saddle heights could reduce chaotic pedaling rhythms during exercise fatigue. Although this study did not investigate the relationship between saddle height and knee injury, most evidence-based studies have supported using saddle heights with 25° knee flexion for beneficial effects in both performance and injury prevention.

After inducing exercise fatigue, the relative variance in cadence frequency for saddle heights with 35° knee flexion was higher than that for saddle heights with 25° knee flexion. Thus, a saddle height with 25° flexion is more appropriate for cyclists. The limitations of our study were the small sample size and the short cycling duration, which was selected because it is difficult to observe exercise fatigue during long-distance cycling.

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