Differences in the Joint Movements and Muscle Activities of Novice according to Cycle Pedal Type

Jeong-Woo Seo1, Dae-Hyeok Kim1, Seung-Tae Yang1, Dong-Won Kang3, Jin-Seung Choi2,3, Jin-Hyun Kim4, Gye-Rae Tack2,3

1Department of Biomedical Engineering, Graduate School of Konkuk University, Chungju, South Korea
2Department of Biomedical Engineering, College of Biomedical and Health Science, Konkuk University, Chungju, South Korea
3BK21 Plus Research Institute of Biomedical Engineering, Konkuk University, Chungju, South Korea
4Department of Sports Rehabilitation, Jeju International University, Jeju, South Korea

Objective: The purpose of this study was to compare the joint movements and muscle activities of novices according to pedal type (flat, clip, and cleat pedal).

Method: Nine novice male subjects (age: 24.4 ± 1.9 years, height: 1.77 ± 0.05 m, weight: 72.4 ± 7.6 kg, shoe size: 267.20 ± 7.50 mm) participated in 3-minute, 60-rpm cycle pedaling tests with the same load and cadence. Each of the subject’s saddle height was determined by the 159° knee flexion angle when the pedal crank was at the 6 o’clock position (25° knee angle method). The muscle activities of the vastus lateralis, tibialis anterior, biceps femoris, and gastrocnemius medialis were compared by using electromyography during 4 pedaling phases (phase 1: 330°-30°, phase 2: 30°-150°, phase 3: 150°-210°, and phase 4: 210°-330°).

Results: The knee joint movement (range of motion) and maximum dorsiflexion angle of the ankle joint with the flat pedal were larger than those of the clip and cleat pedals. The maximum plantarflexion timing with the flat and clip pedals was faster than that of the flat pedal. Electromyography revealed that the vastus lateralis muscle activity with the flat pedal was greater than that with the clip and cleat pedals.

Conclusion: With the clip and cleat pedals, the joint movements were limited but the muscle activities were more effective than that with the flat pedal. The novice could benefit from the clip and cleat pedals regardless of their pull-up pedaling advantage. Therefore, the novice should perform the skilled pulling-up pedaling exercise in order to benefit from the clip and cleat pedals in terms of pedaling performance.

Keywords: Pedal type, Joint movement, Electromyography

INTRODUCTION

The rapid popularization of cycling has resulted in cycles becoming more than a simple means of transport and now being used for recreation and exercise as well. Consequently, interest in improving pedaling ability and preventing injuries has increased. The number of individuals who have their cycle frames fitted for size or use expensive accessories or equipment to improve pedaling ability and prevent injury has increased not only among elite cyclists but also among untrained individuals. Of the two methods, fitting is the method of adjusting the size and angle of the cycle frame, saddle height, and position of the handles to adjust to the rider’s body type and riding style (Bae et al., 2012). This requires the assistance of a trained expert and is not yet widely available in South Korea. The other method of swapping accessories or equipment involves choosing a lightweight frame, adjusting the crankset gear ratio, or selecting a wheel size or pedal type that is better for pedaling. Both methods help to improve pedaling ability and prevent injury. Non-experts and hobbyists tend to prefer selecting and swapping accessories and equipment to fitting because the latter is difficult to find, and the typical accessory that is targeted is the pedals. The pedals are the part that link the rider’s body to the cycle and are the element where force is ultimately applied. The force applied to the pedals is transferred to the crankset. As this force overcomes the resistance and inertia of the crankset, it is converted into energy (Raasch et al., 1997). The advantages of the pedals are that they can be easily replaced by anyone and enable pedaling efficiency to be improved at a lower cost than changes to the frame or wheels.

Pedals can be broadly divided into three types. One is the flat pedals. The flat pedal is the standard pedal used in cycles for the general public. As the foot is simply placed on the top of the pedal without any other fixation device, flat pedals have the advantage of being safer than other pedal types. However, the disadvantage of flat pedals is that a pulling force could not be applied after the pedal reaches the bottom dead center (BDC) of the stroke, when it is at its lowest point relative to the crankset. The second type of pedals is the clip pedals (or toe clips). Clip pedals are shaped like a cage that embraces the foot from
the metatarsals to the tips of the toes. The disadvantages of the clip pedals are that it is awkward to insert and remove the foot from the pedal and that when the foot is fixed with the strap, the foot needs to be detached from the pedal after stopping. On the other hand, the advantage of clip pedals over flat pedals is the ability to apply a pulling force during pedaling. Clip pedals are currently used in track cycling competitions. The third type is the cleat pedals (or clipless pedals), in which the part of the clip pedals that embraces the foot has been eliminated, and the rider wears shoes with cleats on the bottom, which can then be attached to and detached from the pedal. Compared with clip pedals, attachment and detachment are easier for cleat pedals, making them relatively safer. In addition, because the foot is fixed to the pedal as with clip pedals, a pulling force can still be exerted on the pedal. Cleat pedals are considered essential for cross-country, downhill, and road cycling, and use of cleat pedals has been increasing recently not only among elite cyclists but also among non-experts. The disadvantage of cleat pedals is that they require the rider to wear a special shoe with cleats on the bottom.

Hence, several types of pedals have been developed, and physical movements and characteristics differ during pedaling according to the pedal type and the way pedals are connected to the foot. A representative previous study that examined pedaling characteristics according to pedal type measured and compared muscle activities in triathletes who used clip or cleat pedals (Cruz & Bankoff, 2001). The results showed that the use of cleat pedals resulted in decreased activities of the semitendinosus, semimembranosus, biceps femoris, and gastrocnemius lateralis muscles. Several studies have compared pedal types in terms of their effects on muscles in elite athletes, but studies that identified the forces and kinematic forms involved in pedaling with different types of pedals and fixation in non-experts are inadequate. Given that suitable pedal choice improves performance and prevents injuries, the need to identify the muscle activity involved in force generation and movement of the lower body is urgent (Seo et al., 2012). In the case of non-experts, owing to the lack of training in applying a pulling force to the pedals, muscle use and kinematic forms are thought to be similar irrespective of the type of pedal.

Therefore, this study examined the kinematic and muscle activity characteristics in non-experts when pedaling with flat, clip, or cleat pedals, with the aim of providing useful information in choosing the appropriate pedal type for improving performance and preventing musculoskeletal injury.

METHODS

1. Research subjects

The study subjects consisted of 9 healthy novices in their twenties who did not usually participate in cycling, had no musculoskeletal disease, and pedaled normally (age: 24.40 ± 1.90 years, height: 1.77 ± 0.05 m, body weight: 72.20 ± 7.60 kg). All the participants read the explanation of the experiment and signed the consent form prior to participating in the study. The experiment, which adhered to the study plan, was approved by the institutional review board of Konkuk University (7001355-201506-HR-062).

2. Experiment apparatus

All the experiments were performed on a stationary cycle with a roller attached for the subjects to be able to perform identical pedaling on an existing cycle. A three-dimensional (3-D) motion analysis system consisting of 6 infrared cameras (Motion Analysis, USA) and electromyography (EMG; Trigno Wireless EMG Systems, Delsys, USA) were used to measure joint angle, pedal position, and muscle activity. The 3-D motion analysis system and EMG were synchronized, and data were collected at sampling frequencies of 120 and 1,200 Hz, respectively. An SRM power meter (Schoberer Rad Messtechnik, Germany) was used to measure pedaling speed and power, but power did not significantly differ according to pedal type. In order to maintain constant speed and power during pedaling, the training program I-Magic Trainers (Tacx, the Netherlands) and a metronome were used. Pictures of the three types of pedals are shown in (Figure 1). Flat pedals were manufactured “in-house” (Lee et al., 2014). For the clip pedals, the toe clips were acquired from Shimano (DuraAce Pedals PD-7400 with toe clips, Shimano Inc., Japan) and attached to the front of the flat pedals. For the cleat pedals, cleats were obtained from Shimano (SH-XC30, Shimano Inc., Japan), and a fixation device was added to the upper cover of the flat pedals to enable attachment of the cleats. All the pedals were weighted before the experiment to confirm that the weights were identical. For all the pedal types, the footwear used consisted of Shimano cleats with the cleats removed from the bottom.

![Pedal type](image)

Figure 1. Pedal type (left top: flat, right top: clip, and bottom: cleat)

3. Experiment procedure

Prior to the experiment, the participants underwent sufficient stretching and warm-up. Next, 6 reflective markers were affixed to the right lower limb based on the plug-in set. The ASIS marker was affixed to the anterior superior iliac spine; the greater trochanter marker, to the