# OXYGEN CONSUMPTION: EFFECT OF LATERAL PEDAL WIDTH VARIATIONS RELATIVE TO Q-ANGLE IN AVID CYCLISTS

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Twenty cyclists completed four trials at 50% of maximal effort. Trials were performed at four different lateral widths (0, 20mm, 25mm, and 30mm) by adding a Kneesaver™ pedal spacer between the crank arm and pedal. Each trial lasted five minutes, during which analysis of expired air took place, as well as video analysis for digitizing purposes. The aim of the study was to determine if changing this lateral pedal width affected oxygen consumption and if lateral pedal width changed Q-angle in the cyclists. Statistically width did not affect Q-angle or oxygen consumption, however a significant, but small correlation was found between Q-angle and oxygen consumption.

**KEY WORDS:** Q-angle, Oxygen consumption, Cycling

## INTRODUCTION:

During cycling, the primary movement of the lower extremities takes place within the sagittal plane. This motion is crucial for force production, but large loads on the joints may cause biomechanical disfunction in which the rider's efficiency becomes sacrificed, such as from extreme Q-angles (Gregor & Wheeler, 1994). According to Mizuna et al., (2001, p. 834), Q-angle can be defined as, "the angle between a line connecting the center of the patella and the patellar tendon attachment site on the tibial tubercle and a second line connecting the center of the patella and the anterior superior iliac spine on the pelvis when the knee is fully extended". Q-angle normally varies between 6° and 27° (Mizuna et al., 2001). In addition to a decrease in overall power output, a rider with an extreme Q-angle may suffer patellofemoral pain due to pronation and rearfoot eversion (Mizuna et al, 2001). These rotations in the foot region cause tibial and femoral rotation (Heiderscheit et al., 1999). Previous research, such as Faria et al., (2005) indicates poor biomechanical functions and misalignments of the lower extremities may cause injury, possibly leading to a decrease in efficiency. These aforementioned conditions may be caused by poor quadriceps function, vastus-medialis insufficiency, subtalar-joint pronation, poor muscle flexibility, abnormal lower-limb biomechanics, and varus or valgus misalignments (Faria et al., 2005).

The sport of cycling can be affected by many factors such as seat height, crank length, and pedal system. However, at this time, the effect on Q-angle and rider's efficiency by altering lateral pedal width has yet to be studied. The goal of this study was to compare oxygen consumption of cyclists at four different pedal widths. Specifically, does pedal width affect oxygen consumption; if so, in a positive or negative way.

## METHODS:

For this project 20 apparently healthy avid male and female road cyclists between the ages of 18 and 30 were studied. Relative to this study, avid cyclists were defined as cyclists who ride recreationally more than 10 hours per week. Testing took place over a two day period. Each subject provided his/her own road bike equipped with a 9-speed rear hub.

On Day 1 of testing, each subject's mass (kg), height (cm), date of birth, and gender were obtained. Prior to participation, each subject was required to sign appropriate consent forms and answer 'No' to all questions listed on the Physical Activity Readiness Questionnaire (PAR-Q). To control the environment, all testing took place in the Biomechanics Laboratory at Northern Michigan University.

Also performed on Day 1 of the study was a cycling max power test. Max power testing was performed following the 'JBST Bike maxHR (and Pmax) Test Protocol' (Beer, 2006). All cyclists were instructed to wear their preferred cycle shoe, using the pedal system they were most accustomed to. The gearing ratios for all conditions were controlled by the subject depending on the power output required for testing. They were permitted to ride in any gear ratio they deemed appropriate at the beginning of each stage. However, the chosen gear was to be maintained for the duration of the stage. When the given power output was no longer attainable in that gear, the test was terminated, indicating the cyclist's maximum power output.

Power output, heart rate, and cadence were measured and monitored using a CycleOps Power-Tap Cervo 2.4™ (Saris Cycling Group, Inc. Madison, WI) cycling computer. The cycling computer was interfaced with a magnetic bicycle hub installed into the rear wheel of the subject's bicycle and as well as a heart rate monitor worn on the subject's chest. The cycle computer was mounted on the handle bars of the bicycle to provide feedback to the subject. Subjects received motivational feedback during the test from technicians. Mounting and calibration of the cycling computer was done as recommended by Saris Cycling Group, Inc (Madison, WI, USA, 2005).

Day 2 took place at least 24 hours, but no more than 48 hours after Day 1. This involved measurement of the physiological responses to variations in lateral pedal widths while cycling at 50% of the previously determined maximal power. Each rider performed a five minute test for each of four different lateral pedal widths (control = no change from normal pedals, 20mm, 25mm, and 30mm). Each trial was performed one time, in a randomized order. Between each bout the subject had a three minute recovery period to rest. During this period pedal widths were changed by the laboratory technician. Lateral pedal width was altered using Kneesavers™ pedal extensors (Fallbrook, CA). These devices are placed between the pedal and crank, extending the pedal further out from the crank arm (See Figure 1). The power output was monitored via a CycleOps PowerTap™ Cervo 2.4 cycle computer with a technician monitoring to ensure correct power output was maintained throughout the duration of each trial. Upon completion of each event, the cycle computer was linked to a laptop computer to be downloaded and saved for later analysis.

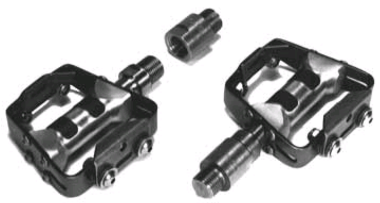

**Figure 1: Kneesaver™ devices**

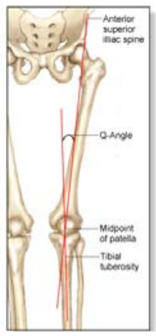


**Figure 2: Q-angle measurements**

To assess Q-angle, reflective markers were placed on the anterior superior iliac spine, mid-point of the patella, and the tibial tuberosity on the subject's right leg. A line was drawn from the iliac spine to the patella and another from the patella to the tibial tuberosity. The angle of measurement was the point at which these two lines crossed (See Figure 2). Q-angle was determined through digital kinematic videography of the landmark sites. A video camera and light was set up two meters in front of the handlebars of the bike in order to examine movement along the frontal plane from the pelvis to the foot. When cued, video was recorded using a Canon Optura 100 at a film speed of 60 frames per second and a shutter speed of 1/500 for three seconds during the second minute of each trial period. For digital analysis, the Peak Motus 8.5 video digitizing software (Vicon Peak, Centennial, CO, USA) was used. In order to measure Q-angle, one full revolution (a full 360° beginning at TDC) of the rider's right leg was digitally analyzed using the three strategically placed reflective markers.

Reference Q-angle measurements were measured during the control width (no change) while riders were seated on their bike pedaling. Q-angle measurements were then gathered during each trial, with these measurements being compared to see if pedal width affected Q-

angle. The point in time at which Q-angle was determined when the foot was the bottom-most point of the stroke, with the leg extended.
The rider's energy output was compared to determine the effect of using different length of the Kneesaver™ device. $VO_2$ $L \cdot min^{-1}$ was the value used for determining oxygen consumption, thus to test our null hypothesis. Oxygen consumption values were the mean $VO_2$ $L \cdot min^{-1}$ values of the final two minutes of breath-by-breath analysis for each subject. The assumption was made that each subject had reached a steady state level after three minutes of riding at 50% of their maximum effort.

**RESULTS:**
Using the statistical analysis software, SPSS version 15 (Chicago, IL, USA) a one-way repeated measures analysis of variance (ANOVA) was run to determine if there was statistical significance between the various widths of the independent variable (Kneesaver™ width) and the dependent variables (Q-angle and oxygen consumption). A Pearson correlation was also run to determine the strength of the relationship Q-angle and oxygen consumption.
Analysis of oxygen consumption relative to pedal width was analyzed using one-way repeated measures ANOVA. There was no difference (P=0.647) in oxygen consumption across the four conditions of pedal width (see Table 1). Effect size using partial eta$^2$ ($\eta_p^2$) were also obtained for oxygen consumption using the formula: $\eta_p^2 = SS_{effect}/(SS_{effect}+SS_{error})$, where $SS_{effect}$=effect variance and $SS_{error}$ = error variance. The scale for classification of $\eta_p^2$ was =0.028=trivial (Comyns et al., 2007).
The second test run was again a one-way repeated measure ANOVA to examine the relationship between Q-angle and pedal width. Similar to oxygen consumption, there was no difference across the pedal width conditions for Q-angle (p=0.458). Effect size for Q-angle using partial eta$^2$ ($\eta_p^2$) classified $\eta_p^2$=0.044= trivial.
The third and final statistical test was a one-tailed Pearson correlation used to examine the relationship between Q-angle and oxygen consumption. With these parameters, there was a significant correlation between Q-angle of the subjects and oxygen consumption, significance p<0.01, r=0.350, $r^2$=.123 explaining only 12% of variance amongst subjects. Although weak, this positive correlation indicates as Q-angle increases, oxygen consumption increases.

**Table 1: Mean ± SD and $\eta_p^2$ for Q-angle and oxygen consumption in the four conditions (Control (0), 20mm, 25mm, and 30mm)**

| n=20 | **Control** | **20mm** | **25mm** | **30mm** | $\eta_p^2$ |
|---|---|---|---|---|---|
| **Q-angle (°)** | 18.5±9.270 | 16.1±8.172 | 16.0±6.378 | 17.4± 7.606 | 0.458 |
| **Oxygen Consumption ($VO_2$ $L \cdot min^{-1}$)** | 1.78±.525 | 1.79±.520 | 1.80±.522 | 1.82±.513 | 0.028 |

**DISCUSSION:**
Major results of this study present no statistically significance differences of Q-angle or oxygen consumption with different pedal widths. By installing Kneesavers™ onto cyclists' normal set-up, the cyclists' neither benefitted nor suffered by the use of extensions. Lateral pedal stance did not affect the Q-angle of the riders. Similarly, Sanderson et al., (1994), found no differences in knee motion of subjects riding with a 10° varus wedge, 10° valgus wedge, and their normal neutral pedal position. When normal bike set up is altered compensation is likely to occur, taking place at the hip, knee, or ankle (Sanderson et al., 1994). Since oxygen consumption was not affected by lateral stance, it is unlikely a wider stance will improve overall performance.
Results of the current study should be further explored and studied, as different approaches in set-up could provide different results. Measurement of Q-angle could be performed manually by adapting the technique described by Herrington and Nester (2004). Herrington and Nester's method involves taking a digital photo, printing, and drawing lines from the

ASIS to mid-patella and tibial tuberosity to mid-patella. Q-angle was then measured at the point of intersection. This procedure could then be repeated during each trial while the foot is in the bottom dead center position. By doing so, the technician could compare the accuracy of digital measurements to hand measurements, which may alter results significantly.
The lack of difference between oxygen consumption and Q-angles are likely due a cyclist's natural ability to adapt (Sanderson et al., 1994). Cyclists may need to perform the trial testing at a higher intensity or for a longer period of time to increase oxygen consumption levels, such as that suggested by Sickle and Hull (2007). Sickle and Hull tested cyclists by altering the anterior-posterior position then performing a ventilatory threshold test. Testing of the foot positions were performed at 90% of threshold in seven minute stages, collecting data during the last three. Also, lack of difference may be due to flaws in the set-up procedure, which could have altered slightly between testing days. For instance, the camera set-up was to be placed directly in front of the leg to be filmed. If video equipment was not placed in the correct location each time, the leg could have been filmed from a slight angle, rather than dead on, thus digital analysis of Q-angle differed slightly. Finally, testing a larger sample size may be beneficial, as to get a larger sample of all body types and athletic abilities. Since this was the first study to the author's knowledge attempting to use Kneesavers™ to examine differences among cyclists, no other results of this kind are available. To concretely determine validity of this study, further research is required.

**CONCLUSION:**
Based on the statistical results of this project, the pedal width does not affect the Q-angle or the oxygen consumption of cyclists. Thus, the null hypothesis, "*there is no economic difference between pedal widths of cyclists*", is accepted. Although there were no statistical differences found between either oxygen consumption compared to pedal width or Q-angle compared to pedal width, there was a correlation between oxygen consumption and Q-angle. This correlation was low, but indicates, as Q-angle increases, oxygen consumption decreases.
The results of this study revealed no overall benefit to cyclists; however, they did not end up being detrimental either. Testing should be performed at an individual level to account for bilateral difference (Sanderson et. al, 1994). This suggests the need for further research using the Kneesaver™ extenders to examine the benefit riders may receive in prevention of over-use injuries, or simply comfort as suggested by the manufacturer (Ice, 2004).

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