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Oxygen consumption, effect of lateral pedal width variation relative to Q-angle in avid cyclists

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

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ABSTRACT

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

BY
MELINDA J. MCCUTCHEON

Twenty cyclists completed four trials at 50% of power output determined from a graded exercise power test. 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 lateral pedal width affected oxygen consumption and if lateral pedal width changed Q-angle in the cyclists. Oxygen consumption was measured by averaging the subject's VO_2 $L \cdot min^{-1}$ over the final two minutes of each stage. Statistically width did not affect Q-angle or oxygen consumption with significance values = 0.458 and 0.647, respectively. However a significant, but low correlation (r= 0.350) was found between Q-angle and oxygen consumption. Although changing pedal widths did not affect the rider's Q-angle or oxygen consumption, further research is needed to test the effects on overall performance.

KEY WORDS: Quadriceps Angle, Power Output, Cycle

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This thesis was written in accordance to the conventions of the Journal of Applied Biomechanics using the most recent version of the ‘Publication Manual of the American Psychological Association’.

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CHAPTER ONE

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, such as extreme Q-angles, may cause biomechanical discrepancies in which the rider's economy becomes sacrificed (Gregor & Wheeler, 1994). According to Mizuno 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". The Q-angle normally varies between 6° and 27°.

Within the context of this study, oxygen consumption was defined as the rate of oxygen uptake during a given period of time. For the purpose of this study, absolute VO_2 $L \cdot min^{-1}$ values were used to maintain consistency across all subjects. Previous research, such as Faria, Parker, and Faria, (2005) indicates poor biomechanical functions and misalignments of the lower extremities may cause injury. 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 (Mizuno et al., 2001). Rotations in the foot region cause tibial and femoral rotation (Heiderscheit, Hamill, & Van Emmerik, 1999). 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).

Rider performance 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 economy by altering lateral pedal width has yet to be studied. The goal of this study was to compare effects of lateral width on Q-angle and oxygen consumption. Specifically, does pedal width effect oxygen consumption; if so, in a positive or negative way. Also, was Q-angle affected by varying pedal widths.

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. Riders did not have to be competitive, but this definition did not include those who bike purely as transportation. This study was not aimed at elite riders due to the fact that elite riders are concerned with bike weight, aerodynamics and technical aspects of competition; however it did not disqualify them from being a subject. Testing took place over a two day period with each subject providing his/her own road bike equipped with a 9-speed rear hub.

On Day 1 of testing, subjects' weight (kg), height (cm), date of birth, and gender were obtained. Prior to participation, each subject was required to sign appropriate consent forms (Appendix A) and answer 'No' to all question listed on the Physical Activity Readiness Questionnaire (PAR-Q) (Appendix B). To control the environment, all testing took place in the Biomechanics Laboratory at Northern Michigan University. All procedures were cleared from and approved by the Human Subjects Research Review Committee #HS07-104 (Appendix C).

Also performed on Day 1 of the study was a cycling maximum power test. Max power testing was performed following the 'JBST Bike maxHR (and Pmax) Test Protocol' (Beer, 2006; Appendix D). All cyclists were instructed to wear their own personal cycle shoe, using the pedal system with which they typcially ride. 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 maintained for the duration of the stage while the rider maintained a seated position. 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 the heart rate monitor worn on the subject's chest. The cycle computer was mounted on the handle bars of the bicycle. 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 testing 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 lab technician. Lateral pedal width was altered using Kneesavers™ pedal extensors (Fallbrook, CA). These devices were placed between the pedal and crank, extending the pedal further , by 20mm, 25mm, and 30mm, out from the crank arm on each side (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. To maintain a consistent power output, gear ratio was kept constant throughout all stages. Since gears did not change and power output was maintained, cadence did not change. All trials were again perfomed in the seated position. Upon completion of each event, the cycle computer was linked to a laptop computer to be downloaded and saved for later analysis.

Figure 1: Diagram of Kneesavers™ device which was placed between pedal and crank arm. (Ice et al., 2008)

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 right leg of each subject. 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 (Figure 2). Q-angle was determined through digital kinematic videography of the landmark sites. A video camera and light were 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 20 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, 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. Markers were attached directly to the skin, or to cycling shorts covering the anatomical marker.

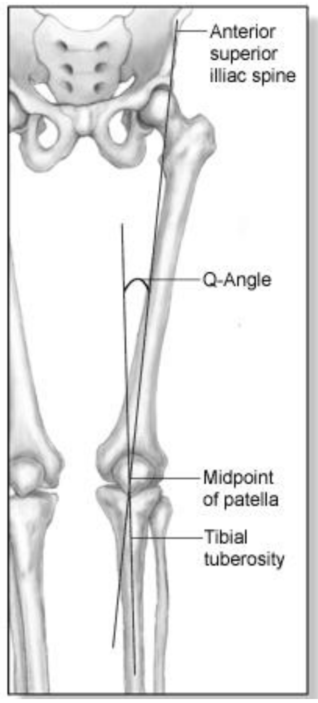


Figure 2: Illustrates how to measure Q-angle. The superior-most point is located at the Anterior superior iliac spine, mid point is the center of the patella, and the third point is the tibial tuberosity (LeadingMD, Inc, 2003).

Reference Q-angle measurements were determined 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 of Q-angle was measured when the pedal was in the dead bottom center position, the point at which the leg was the most extended while on the bike.

Results for each bout were recorded to assess if differences in oxygen uptake were evident, noting which length Kneesaver™ was used and its effect on the oxygen consumption, measured via oxygen consumption, or VO_2 $L \cdot min^{-1}$, as all subjects were compared to themselves as well as each other. VO_2 $L \cdot min^{-1}$ was the value used to test the null hypothesis comparing oxygen consumption across all four conditions. At the completion of the each subject's trials, the raw breath-by-breath data was examined using the final four, 30 second intervals. To determine mean VO_2 $L \cdot min^{-1}$ values, the last two minutes of oxygen consumption values were averaged. This mean value was then used to compare each subject against themselves to examine for change. The assumption was made that each subject had reached a steady state level after three minutes of riding at 50% of their maximum effort (McArdle, Katch, & Katch, 2007).

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 a 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 of Q-angle to oxygen consumption.

Analysis of oxygen consumption relative to pedal width was examined using a one-way repeated measure ANOVA. Data examined were from each of the four trials for all subjects (n=20). At $p<0.05$, significance= 0.647. Thus, there was no effect of pedal width on oxygen consumption in subjects (n=20). Effect size using partial eta^2 (η_p^2) was 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 (Table 1). The scale for classification of η_p^2 was <0.028 = trivial (Comyns, Harrison, Hennessey, & Jensen, 2007).

The second test run was again a one-way repeated measure ANOVA to examine the relationship between Q-angle and pedal width. There was no significant difference between the four conditions at $p<0.05$, significance= 0.458, indicating again, pedal with did not have an effect on Q-angle for subjects (n=20). Effect size for Q-angle using partial eta^2 (η_p^2) classified η_p^2 <0.044= trivial (Table 1).

Table 1: Mean ± SD and η_p^2 for Q-angle and Oxygen consumption at the four conditions (Control (0), 20mm, 25mm, and 30mm)

n=20	Control	20mm	25mm	30mm	η_p^2
Q-angle (°)	18.45± 9.27	16.12± 8.17	16.01± 6.38	17.38± 7.61	0.458
O^2 Consumption (VO_2 L·min^{-1})	1.78± .52	1.79± .52	1.80± .52	1.82± .51	0.028

The third and final statistical test was a one-tailed Pearson correlation used to examine the relationship between Q-angle and oxygen consumption at $p<0.01$. With these parameters, there was a significant correlation between Q-angle of the subjects and oxygen consumption, significance $p<0.01$, $r=0.350$, $r^2=.1226$, $y= 0.0223x + 1.4236$; explaining approximately only 12% of variance amongst subjects. Although weak, this positive correlation indicates as Q-angle increases, oxygen consumption increases (Figure 3).

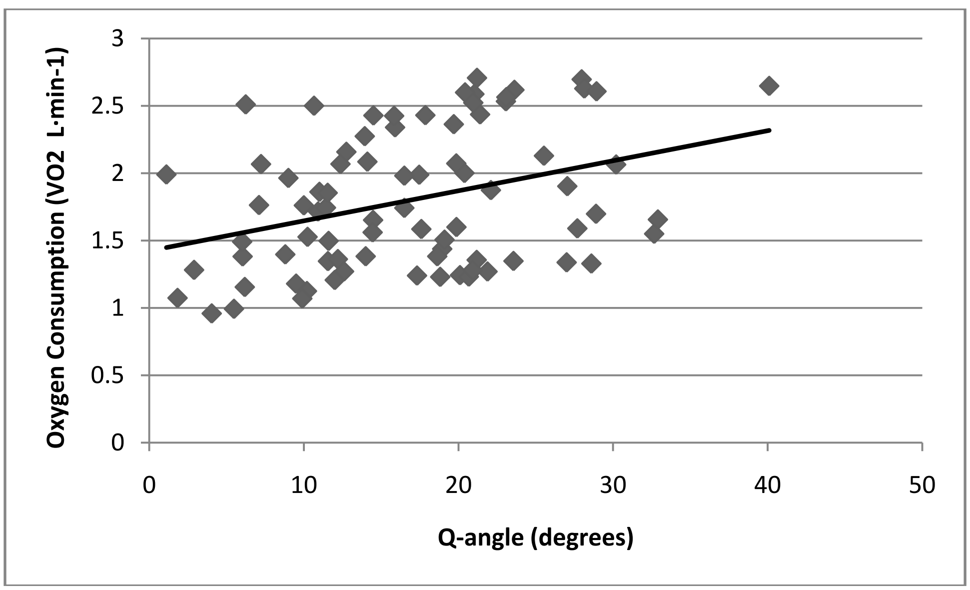


Figure 3: Correlation between Q-angle and oxygen consumption. $y= 0.0223x + 1.4236$, $R^2= 0.1226$.

DISCUSSION

Major results of this study reveal 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 benefited nor suffered by the use of extensions. Lateral pedal stance did not affect the Q-angle of the riders. Similarly, Sanderson, Black, and Montgomery, (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 setup 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 at this particular intensity. However, the stages for this study were relatively short and moderate in intensity, so performance could be affected differently in higher intensity settings or over a longer period of time.

Although there was no significant difference in Q-angle measurements or oxygen consumption at the four conditions, the low correlation between Q-angle and oxygen consumption indicates the need for further exploration. With larger Q-angles, oxygen consumption increased, which indicates riders with wider Q-angles may not be as economic as their narrower counterparts. Results of Table 1 showed no trends between the various widths (i.e. oxygen consumption decreased between 20mm and 25mm, but increased between 25mm and 30mm). Explanation for this occurrence may be due to a cyclist's natural tendency to adapt, possibly causing them to overcompensate for their position (Sanderson et al., 1994).

Results of the current study should be further explored, as different approaches in set-up could provide different results. One study by Sanderson et al., (1994) looked at bilateral differences when using varus and valgus wedges under the shoe of cyclists. Results showed some subjects responded differently in each leg. This validates the need for further exploration of pedal width alterations. The current study only examined Q-angle effects on one leg (although both legs were undergoing the conditional change), but perhaps there is a need to examine Q-angle changes in both legs simultaneously, as suggested by Livingston and Spaulding (2002) and Sanderson et al., (1994).

In addition to measuring effects of both legs, 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 it, and drawing lines on the print 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. Livingston and Spaulding (2002) claimed Q-angle measurements differ depending on the foot position of the subject, with differences ranging from 0.2° to 1.3°. Livingston and Spaulding used light emitting diodes to measure Q-angles while subjects stood in a standardized position. Based on previous research, many questions remain regarding the best method for measuring Q-angle and more research is required to determine a standardized method for establishing Q-angle while subjects are in motion.

The lack of difference between oxygen consumption and Q-angles at various pedal widths is likely due a cyclist's natural ability to adapt (Sanderson et. al, 1994). Sickle and Hull examined ventilatory threshold while altering the anterior-posterior foot position on the pedal (2007). Testing of the foot positions were performed at 90% of threshold in seven minute stages, with data collected during the last three minutes. However, Sickle and Hull found, both on an individual level and as a group, that VO_2 was not significantly affected by anterior/posterior foot position ($p<0.156$). Despite the lack of significant differences reported by the above mentioned studies, most authors agree, varying foot placement has the potential to greatly benefit performance of a rider (Sickle & Hull, 2007; Sanderson et al., 1994). One suggestion may be to test cyclists 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). Although authors state these position alterations may affect performance, their results state otherwise, thus controversy exists between perceived potential and observed data.

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, 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 not rejected. 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, it 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).

CHAPTER II

REVIEW OF THE LITERATURE

The invention of the bicycle dates back to the 19th century. Just before the turn of the 20th century, the "safety" bicycle was invented, introducing the bicycle as we know it today (small even wheels, chain drive, rubber wheels). Throughout the centuries, cycling has evolved from a means of transportation to a competitive past time of world class athletes. Several factors are currently known to affect the economy, thus the performance of the cyclist. For example, Zamparo, Minetti, and Pramero, (2002) studied the effects of varying saddle height and crank arm length in cyclists, while Atkinson, Davison, Jeukendrup, and Passfield, (2003) examined effects of frame size, work load, and pedal rate.

The sport of cycling goes far beyond repetitive pedaling motions. Much research has been done on various aspects of this sport from saddle height to crank length. The amount of oxygen uptake per minute may be greatly affected by many aspects of cycling including body type, cardiovascular endurance, leg structure, and bike structure. Oxygen consumption can be measured by testing submaximal VO_2 per unit of body weight required to perform a given task. Economy is reflected by observing the differences in the VO_2 at given mechanical workloads (Faria et al., 2005).

One major component of cycling is force production. Force can be measured at the ground (via strain gauges in the hub), at the pedal, or even at the knee to determine what is occurring at that particular level. Much research has been done to determine what forces are placed on the knee joint and what effects this has on the cyclists. Millslagle, Rubbelke, Mullin, Keener, and Swetkovich, (2004) notes the effect of optimal foot positioning in producing lower skeletomuscular and ligament stress on the knees throughout a cycling revolution.

One area of interest that has little, if any, research is the effect of individual's quadriceps angle on the overall force production of the rider. Q-angle, according to Ericson and Nisell (1984), is "the position of the knee joint relative to the pedal is of great importance for the magnitude of the moments acting about the knee in the coronal plane. Subjects obtained a reduction of the varus knee load and a simultaneous increase in valgus load when cycling in the pronounced adducted, knees-close position" (page 42). This position is rather similar to the knees-close position often seen among racing cyclists (Figure 4).

Figure 4: Closed Knee versus neutral knee position when cycling. Left photo illustrates a "closed knee" position (Courtesy of Rob Jones/Canadian Cyclist), while the photo on the right is a "straight" or neutral stance (Courtesy of USA Cycling).

One device which widens the lateral stance by extending the pedals out, is the Kneesaver™ (Ice, 2008). Presently, no scientific data exists which has measured the effect Kneesavers™ have on the performance of a cyclist. Anecdotal information is available stating the decrease in hip and knee pain; however, currently there are no physiological links to the benefit of this device (Ice, 2008). Upon installation of the Kneesaver™, foot position is moved laterally in an attempt to widen the rider stance, as to avoid the "knees-closed" position and lessen Q-angle. Other methods to alter Q-angle include using wedges (Sanderson et al., 1994) and various foot positions (Livingston & Spaulding, 2002).

Anatomy of a Cyclist

Q-angle Anatomy

Quadriceps angle (Q-angle) is formed by two lines formed by the lower body (Figure 2). The superior angle extends from anterior superior iliac spine to the mid-point of the patella, while the inferior angle extends from mid-patella to the tibial tubercle (Herrington & Nester, 2004). “When the Q-angle exceeds 15-20º it is thought to contribute to knee extensor mechanism dysfunction and patellofemoral pain” (Byl, Cole, & Livingston, 2000, p. 30). If a subject suffers patellofemoral pain, performance during the task is likely inhibited by the pain (Byl et al., 2000). In addition, tendons, ligaments, and muscles will not have optimal angles for movement and performance.

There has been much debate regarding the accuracy of Q-angle measures because the patella is a mobile structure. For the most accurate Q-angle measurement the patella must be centered in the trochlear groove (Herrington & Nester, 2004). Measurements may not be consistent if the quadriceps muscles supporting the knee joint become abnormally stressed, causing the patella to shift and create a more obtuse angle. Also, as noted by Sanderson et al., (1994) subjects have a natural ability to adapt to changes in set-up. Since Q-angle is formed from many segments throughout the lower body, these must be examined in detail.

The Hip Joint

The hip joint is important in the act of cycling because it allows for femur rotation along the sagittal plane. The hip joint is comprised of the ilium, ischium, and pubis bones which form a socket for the ball of the femur. The lower portion of the hip joint, the femur, is the largest bone in the human body. The head of the femur sits in the concave socket of the acetabulum formed by the ischium, ilium, and pubis, (Shier, Bulter, & Lewis, 2003). This joint is one of few “ball and socket” joints found in the human body. Its structure allows for flexion, extension, internal and external rotation. The joint also allows for abduction, adduction and circumduction of the leg.

Movement occurring within the frontal plane of the hip joint is vital to force production in cycling. Contraction of the adductor longus or abductor muscles allow for abduction and adduction motions along the frontal plane of the hip joint. Abduction allows the limb to be moved laterally from the midline of the body, while adduction moves the limb medially.

The Knee Joint

Distal from the hip joint, the knee joint is a complex joint consisting of capsules, ligaments, tendons, and bone. The knee joint houses the distal end of the femur bone which forms a portion of this condylar joint along with the proximal end of the tibia and the patella (Kreighbaum & Barthels, 1995). The primary movements that occur in the knee joint are flexion and extension. Very little medial or lateral rotation is able to take place without suffering damage to the cartilaginous joint; however a small amount of rotation is available while in a flexed position.

The superior end of the knee joint is created by the distal end of the femur. The medial and lateral condyles of the femur articulate with the proximal end of the tibia. These condyles meet the tibia plateau; both are covered with articular cartilage to form a smooth surface in which movement takes place. The cartilaginous structures of lateral and medial menisci are crucial in cushioning impact incurred within the knee joint, (Sheir et al., 2003).

Several critical ligaments are found in the knee joint and help stabilize this vulnerable structure. The anterior and posterior cruciate ligaments (ACL and PCL) help stabilize the knee along the anterior-posterior plane, whereas the medial and lateral collateral ligaments resist medial-lateral movement in the frontal plane.

The Ankle Joint

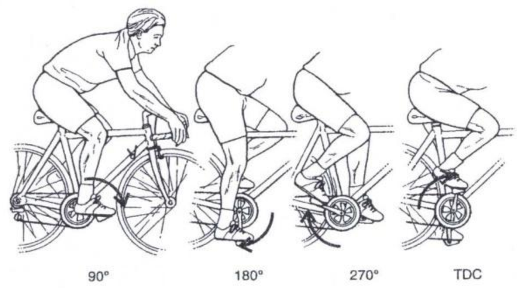
The ankle joint is primarily made up of three main bones, the distal end of the tibia and fibula, as well as the talus. The deltoid ligament connects the medial tibia to the talus while the posterior and anterior talofibular ligaments hold the lateral fibula to the talus. Also extending from the distal end of the fibula is the calcaneolfibular ligament, which attaches to the calcaneus. Foot positioning greatly affects the ankle joint. In a "toe-out" position, the ankle will circumduct, positioning the calcaneus more medially than the forefoot, while a "toe-in" position causes the opposite to occur.

Muscles of the Lower Body

There are three primary muscle groups involved in cycling (See Figure 5). Beginning at the lowest portion of the lower leg, the gastrocnemius and soleus muscles form the calf muscle and the tibialis anterior located on the frontal side of the lower leg. The gastrocnemius and soleus muscles are used primarily for eccentric contractions of the down stroke during a pedal revolution, especially during climbing bouts. During the upstroke phase of pedaling the tibialis anterior muscle is recruited, dorsiflexing the forefoot.

The second major muscle group is found on the anterior portion of the thigh. Referred to as the quadriceps femoris, this group of muscles helps in the extension of the knee and flexion of the hip joints. This group of muscles is comprised of the rectus femoris, vastus lateralis, vastus medialis, and the vastus intermedius. These four muscles combine at the distal end of the thigh to form the quadriceps tendon and connect to the patella.

The third muscle group crucial to the sport of cycling is the posterior thigh, or hamstrings. The hamstring group consists of the biceps femoris, semitendenosus, and semimembranosus. These muscles cause flexion of the knee and extension of the hip, while the tibialis anterior dorsiflexes the foot, bringing the two segments of the leg together on the posterior side of the knee.



Muscles	Cycling Phases TDC-90	90–180	180–270	270-TDC
Biceps Femoris	*	***	*	*
Gastrocnemius	**	***	**	*
Gluteus Maximus	***	**	*	*
Gracilis	**	*	*	
Rectus Femoris	**	**	*	***
Sartorius	*	*	*	*
Semimembranosus	**	***	**	*
Tensor Fascia Latae	*	*	*	*
Tibialis Anterior	**	**	**	***
Vastus Lateralis	***	**	*	**
Vastus Medialis	***	**	*	**

* = low activity
** = moderate activity

Figure 5: Muscle stimulation during phases of pedal revolution (Hamill & Knutzen, 2003, p. 191).

Biomechanical Factors of Cycling

A pedal revolution is one 360 degree rotation about the bottom bracket of a bicycle. This movement consists of a down-stroke with simultaneous up-stroke of the opposite foot. During the down-stroke motion, or power phase, the quadriceps group is the primary muscle group being targeted from top dead center (TDC) to 180°. Although, much of the power from this phase comes from the momentum of the weight of the leg, the strength of the muscle also is important. According to Gregor and Wheeler, (1994) “It has become clear that the hip and the knee perform very different actions....the hip consistently produces an extensor moment while the knee yields an extensor moment and then flexor moment prior to attaining 180º” (p. 122).

While one leg is performing a power phase, or down stroke, the opposite leg is simultaneously performing the recovery phase, or upstroke. The down stroke can be broken into two smaller phases, TDC to 90° and 90° to 180°. From TDC to 90°, the primary movement taking place is a concentric contraction of the quadriceps (vastus lateralis, vastus medialis, and rectus femoris), gracilis, gastrocnemius, and tibialis anterior and a concentric contraction of the gluteus maximus. During the 90° to 180° movement, the biceps femoris, gastrocnemius, semimembranosus are primarily concentrically contracting. The recovery phase takes place during the 180° to 270° and 270° to TDC° phases. A series of concentric contractions take place during the 180° to 270° and 270° to TDC phases, resulting in flexion of the knee and hip. From 180° to 270° the primary muscles involved are the gastrocnemius, semimembranosus, and tibialis anterior (Figure 5). These contractions continue from 270° to TDC, with concentric contractions now in the rectus femoris, vastus lateralis, vastus medialis, and more-so in the tibialis anterior (Hamill & Knutzen, 2003, p. 191).

Cycling forces and power output

The forces and moments exerted during cycling are commonly measured either by strain gauges applied along the crank arms or by different types of strain gauges applied to the pedal (Atkinson et al., 2003), or strain gauges within the rear wheel hub (CycleOps Power Tap, 2005). There are several factors affecting cycling power, as shown in Figure 3.5 below. The majority of force generated throughout a pedal cycle is produced throughout the down stroke (Figure 6) (Gregor & Wheeler, 1994). Specifically, “force exertion is maximum when the position of the crank is horizontal (90° crank angle)” (Hoes, Binkhorst, Smeekes-Kuyl, & Visser, 1968, p. 39). Many factors may contribute to the amount of power that a rider can produced (Figure 7), such as bicycle set-up and rider positioning on the bike (Wancich, Hodgkins, Columbier, Muraski, & Kennedy, 2007) as well as velocity and training techniques (Atkinson et al.,2003).

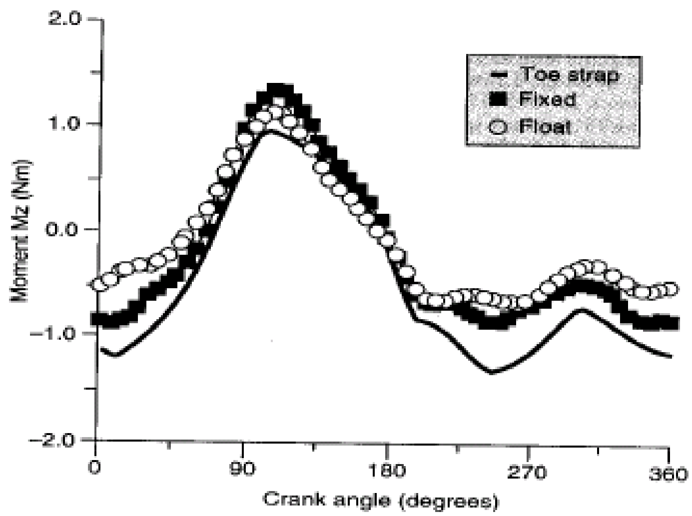


Figure 6: Various pedal techniques in cycling, no matter the pedal method, the greatest forces produced are at between 90° and 180° (Gregor & Wheeler, 1994, p. 129).

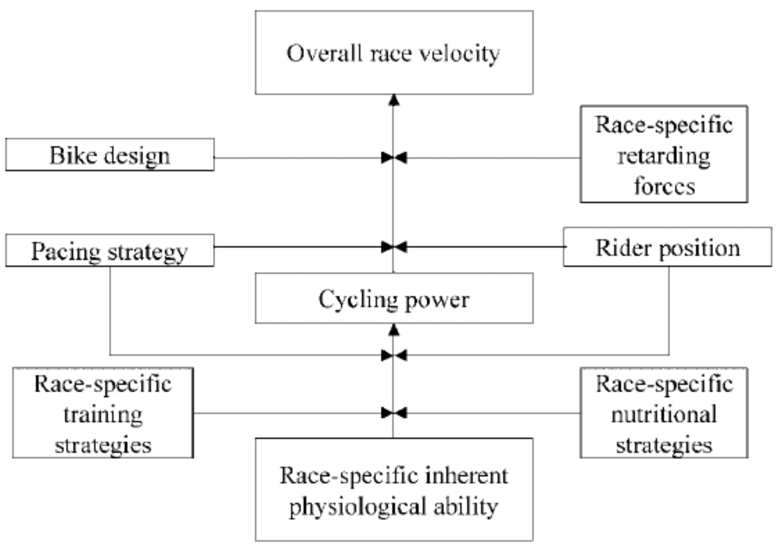


Figure 7: Diagram which exhibits factors effecting cycling output, (Atkinson et al., 2003, p. 768).

Assessing Cycling Performance

Typically, piezo-electric transducers mounted on the pedal are used to collect 3-D forces, (Mornieux, Zameziati, Mutter, Bonnefoy, & Belli, 2006). Although it is important to measure, analyze and compare forces acting on the knee joint on all three planes, (Ericson, Nisell, and Ekholm, 1984; Mornieux et al., 2006) it is possible to examine power production at the wheel-road interface using a strain gauge instrumented hub (CycleOps, 2005). This does not examine any one portion of the lower extremity, rather, the power produced as a whole. Biomechanical alterations of the Q-angle can be measured in several ways, such as through digital video analysis while examining along the frontal plane. Oxygen uptake can be measured using a breath-by-breath metabolic analyzer. By measuring the relationship of Q-angle to oxygen consumption using various pedal widths one may be able to determine if a wider Q-angle allows for lower oxygen consumption without a loss of power output (Too, 1990)

Injuries

The majority of muscular demand in cycling comes from the lower extremities of the body, primarily the legs. Since the motion of cycling is repetitive, often for long periods of time, overuse knee injuries may occur in cyclists (Gregor & Wheeler, 1994). Periodically, high loads are placed upon the joints, which may lead to pain associated with injuries at the knee. High repetitive loads have the ability to emphasize biomechanical dysfunctions within the leg, often exhibited in the knee (Gregor & Wheeler, 1994). Lower extremity dysfunctions can be accentuated by valgus or varus conditions, attributing to an abnormal Q-angle. Heiderscheit et al. (1999) suggests 25% to 30% of all running injuries occur within the patellofemoral joint due to excessive Q-angle measurements. Likewise, Wanich et al. (2007), claims nearly 60% of cyclists suffer from patellafemoral related injuries, citing varus and valgus misalignments as one possible source for those injuries.

Knee Pain in Cyclist

Results from Mornieux's study suggest using cycling in rehabilitation for patients with knee injuries. Cycling with the knees close decreased the mean maximum varus load from 24.5 Nm to 11.2 Nm. Varus load moment is the dominant load acting in the coronal plane during cycling on a bicycle ergometer (Gregor & Wheeler, 1994). One hypothesized method for accounting for knee pain in cyclists is the use of Kneesavers™ (Ice, 2008). Kneesavers™ are a stainless steel device developed to expand the lateral distance from pedal to crankarm. These threaded expanders screw into a clipless pedal on one end and the crankarm on the opposite. Kneesavers™ devices act by expanding lateral width of the cyclist. "This modification can often minimize or eliminate hip, knee, ankle or foot pain for many people" (Ice, 2008).

Adjustments

Faria et al., (2005) suggests a cyclist's performance depends greatly on the crank length, seat height, and tube angle. To decrease drag forces, aerodynamic clothing can be worn as well as maintaining an aerodynamic profile. Cyclists have several options for correction of anatomical misalignments such as foot orthoses (Murley & Bird, 2006), saddle height adjustments (Too, 1990), and shoe-cleat interface, (Gregor & Wheeler, 1994) and crank arm length (Too, 1990). Saddle to pedal distance changes the kinematics of cycling in that joint angles, muscle lengths, and muscle moment arms are all altered, whether the saddle is raised or lowered (Too, 1990). Figure 6 shows the differences between toe strap, fixed, and floating pedal systems in regards to maximum power production based on degree of pedal cycle. The shoe-pedal interface exhibiting the greatest force was the fixed pedal system (Gregor & Wheeler, 1994). Murley and Bird,

(2006) suggests foot orthoses can influence reactive moments of the lower leg muscles, thus increasing performance. If correcting for varus and valgus misalignments by using foot orthoses, research leaves us questioning if varying lateral pedal width may increase these positive effects even more. The Kneesaver™ devices widen lateral pedal width in an attempt to benefit the rider's oxygen consumption. Presently there is no data justifying Kneesavers™ claims, however anecdotal information claims state, "Kneesavers™ help eliminate foot, ankle, knee, or hip pain for cyclists..." also claiming. Also, "Distancing the pedals further apart improves the biomechanics or cyclists with any of the above mentioned conditions, thereby improving pedaling economy and power for both competitive and recreational cyclists" (Ice, 2007).

Summary

Few, if any studies, have focused solely on how Q-angle might affect power output and oxygen consumption. However, research has shown Q-angle may lead to knee pain in cyclists (Mizuno et al., 2001). Currently, cyclists are able to have their bike customized specifically to their anatomical alignments through alterations of saddle height, frame size, handle bar height, and crank length. If lateral pedal stance alterations can positively affect performance, cyclists could then customize that aspect of the bike as well. If research shows significant increase in overall oxygen consumption when altering pedal width relative to cyclist's Q-angles, it could prove significant for avid cyclists looking to improve performance.

CHAPTER III

CONCLUSION AND RECOMMENDATIONS

Based on the statistical results of this project, 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 not rejected. 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, so does the oxygen consumption, thus oxygen consumption decreases.

The results of this study revealed no overall benefit to cyclists; however, it did not end up being detrimental either. Testing should be performed at an individual level to account for bilateral difference, as all riders may not respond in similar ways and differences may be evident between each leg of a rider (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).

Many questions still remain regarding the effect of lateral pedal width variations on cyclists. These questions indicate the need for further research on the subject, which may include:

1. Examining the effect of a narrow pedal stance on oxygen consumption of riders. Does a narrower stance affect performance, injury rates, or oxygen consumption?

2. Examining the effect of wider pedal widths on muscular activity of the upper leg. Are muscle recruitment patterns observed at various pedal widths? Does this correlate with an increase or decrease in oxygen consumption? How could this be useful in attempting to recruit larger muscle groups for performance purpose?

The above mentioned recommendations for research could help clarify the effect of pedal widths on different physiological and biomechanical aspects of cycling. If subsequent research shows pedal widths cause significant increases in performance by altering muscle activity or energy expenditure, pedal width alterations have the potential to become as customizable as saddle height. Preliminary data does not show an effect on oxygen consumption with pedal width variations; however, further research is suggested.

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APPENDIX A

SUBJECT CONSET FORM

NORTHERN MICHIGAN UNIVERSITY
DEPARTMENT OF HPER

CONSENT TO ACT AS A HUMAN SUBJECT

Subject Name (print):____ Date __________

1. I hereby volunteer to participate as a subject in exercise testing. I understand that this testing is part of a study titled: "Force Production: Effect of Lateral Pedal Variation Relative to Q-angle in Avid Cyclists." The purpose of the study is to investigate the effect of lateral pedal widths on the overall forces produced while cycling.

   I hereby authorize Randall L. Jensen, Melinda McCutcheon, and/or appropriate assistants as may be selected by them to perform on me the following procedures:

   (a) A two day study consisting of a Maximal Power test followed by breath-by breath data collection at 50% of my max effort 24-48 hours after max test.

   (b) To have me participate in five-minute cycling bouts at four lateral pedal widths, one time with three minute rest periods between each bout. I'm aware of the time it may take for full testing.

   (c) I understand I will be working at a workload set at 50% of my Max power output.

   (d) Prior to beginning testing, my height (cm), weight (kg), date of birth and gender will be recorded.

   (e) Q-angle will be measured by using markers placed on my hip, knee and ankle then analyzed digitally.

   (f) My breath-by-breath data will be collected, in which case I will be required to wear a mass flow sensor and nose clip. I understand this may not be comfortable, but is not harmful.

   (g) During all exercise bouts I will have a Polar Heart Rate Monitor placed on my body to monitor the activity of my heart while cycling.

2. The procedures outlined in paragraph 1 [above] have been explained to me.

3. I understand that the procedures described in paragraph 1 (above) involve the following risks and discomforts: temporary muscle pain, muscle fatigue, and muscle soreness may occur but is unlikely. There is a possibility of abnormal changes in my heart rate or blood pressure or even of a heart attack during the tests. However, I understand that that my heart rate will be monitored during the testing and that I can terminate any test at any time at my discretion. I understand I am able to cease testing due to any other discomforts I experience and feel uncomfortable with such as dizziness, light-headedness, shortness of breath, etc.

4. I have been advised that the following benefits will be derived from my participation in this study: aside from the educational benefit of learning the biomechanics of a pedaling cyclist, there are no direct benefits to me.

5. I understand that Randall L. Jensen, Melinda McCutcheon, and/or appropriate assistants as may be selected by them will answer any inquiries that I may have at any time concerning these procedures and/or investigations.

6. I understand that all data, concerning myself will be kept confidential and available only upon my written request. I further understand that in the event of publication, no association will be made between the reported data and myself.

7. I understand that there is no monetary compensation for my participation in this study.

8. I understand that in the event of physical injury directly resulting from participation, compensation cannot be provided.

9. I understand that I may terminate participation in this study at any time without prejudice to future care or any possible reimbursement of expenses, compensation, or employment status.

10. I understand that if I have any further questions regarding my rights as a participant in a research project I may contact Dr. Cynthia Prosen of the Human Subjects Research Review Committee of Northern Michigan University (906-227-2300) cprosen@nmu.edu . Any questions I have regarding the nature of this research project will be answered by Dr. Randall Jensen (906-227-1184) rajensen@nmu.edu or Melinda McCutcheon (906-227-2540) mmccutch@nmu.edu .

Subject's Signature:____

Witness:____ Date:_________

APPENDIX B

PHYSICAL ACTIVITY READINESS QUESTIONAIRE

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____________________

SIGNATURE ____________________ DATE ____________________

SIGNATURE OF PARENT ____________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

continued on other side...

APPENDIX C

HUMAN SUBJECTS RESEARCH REVIEW COMMITTEE APPROVAL LETTER

Northern Michigan University

Continuing Education & Sponsored Programs
1401 Presque Isle Avenue
Marquette, MI 49855-5325

April 25, 2007

TO: Melinda J. McCutcheon
HPER

FROM: Cynthia A. Prosen, Ph.D.
Dean of Graduate Studies & Research

RE: Human Subjects Proposal # HS07-104
"Force Production: Effect of Lateral Pedal Variation Relative to Q-angle in Avid Cyclist"

The Human Subjects Research Review Committee has reviewed your proposal and has given it final approval. To maintain permission from the Federal government to use human subjects in research, certain reporting processes are required. As the principal investigator, you are required to:

A. Include the statement "Approved by HSRRC: Project # (listed above) on all research materials you distribute, as well as on any correspondence concerning this project.

B. Provide the Human Subjects Research Committee letters from the agency(ies) where the research will take place within 14 days of the receipt of this letter. Letters from agencies should be submitted if the research is being done in (a) a hospital, in which case you will need a letter from the hospital administrator; (b) a school district, in which case you will need a letter from the superintendent, as well as the principal of the school where the research will be done; or (c) a facility that has its own Institutional Review Board, in which case you will need a letter from the chair of that board.

C. Report to the Human Subjects Research Review Committee any deviations from the methods and procedures outlined in your original protocol. If you find that modifications of methods or procedures are necessary, please report these to the Human Subjects Research Review Committee before proceeding with data collection.

D. Submit progress reports on your project every 12 months. You should report how many subjects have participated in the project and verify that you are following the methods and procedures outlined in your approved protocol.

E. Report to the Human Subjects Research Review Committee that your project has been completed. You are required to provide a short progress report to the Human Subjects Research Review Committee in which you provide information about your subjects, procedures to ensure confidentiality/anonymity of subjects, and the final disposition of records obtained as part of the research (see Section II.C.7.c).

F. Submit renewal of your project to the Human Subjects Research Review Committee if the project extends beyond three years from the date of approval.

It is your responsibility to seek renewal if you wish to continue with a three-year permit. At that time, you will complete (D) or (E), depending on the status of your project.

kjm

Telephone: 906 227-2102 ■ FAX: 906 227-2108
E-mail: conteduc@nmu.edu ■ Web site: www.nmu.edu/ce

APPENDIX D

PROTOCOL USED FOR TESTING: ADAPTED FROM
JOE BEER (2006) MAX TEST PROTOCOL

"The MAX test" *Total Time: 10-15 minutes, excluding warm-up*			
STAGE	**TIME (mins)**	**EFFORT Watts (mph)**	**NOTES**
0	**5**	100W men/ 75W women (10 mph)	WARM-UP FOR 5 MINS
1	**1**	150W men/ 100W women (12 mph)	Ride for 1-minutes noting HR in the final 10 seconds
2	**1**	170W (14mph)	Ride for 1-minute noting HR in the final 10 seconds
3	**1**	190W (16mph)	Ride for 1-minute noting HR in the final 10 seconds
4	**1**	210W (17mph)	Ride for 1-minute noting HR in the final 10 seconds
5	**1**	230W (18mph)	Ride for 1-minute noting HR in the final 10 seconds
6	**1**	250W (20mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
7	**1**	270W (22mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
8	**1**	290W (24mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
9	**1**	310W (26mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
10	**1**	330W (28mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
11	**1**	350W (30mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
12	**1**	370W (32mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
13	**1**	390W (34mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
14	**1**	410W (36mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
15	**1**	430W (38mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
16	**1**	450W (40mph)	Ride for 1-minute noting HR in the final 10 seconds if failure to complete whole minute, terminate test and begin cool-down.
0	**5-8**	100-125 W	Cool-down

APPENDIX E

PERMISSION FOR USE OF FIGURE 1

Hi Melinda:

My address is: PO Box 2466
Fallbrook, Calif. (92028)

I'm glad to hear you are entering into the final stages of your study of Kneesavers.....what kind of
preliminary power submaximal power/energy efficiencies did you find.........or have you computered that yet?

You have my permission to use anything you want including photographs on the Kneesaver.net website.

Thank you!

Randy Ice P.T., C.C.S.
SCOR Productions

APPENDIX F

PERMISSION FOR USE OF FIGURE 2

Hello Melinda,
Thanks for the email and we appreciate you asking for permission. I have attached the picture for you to use. Good luck in your project.

Thanks again,
LeadingMD.com, inc.

-----Original Message-----
From: Melinda J McCutcheon [mailto:mmccutch@nmu.edu]
Sent: Friday, March 28, 2008 8:47 AM
To: support@leadingmd.com
Subject: Permission for use of figure

Dear Leading Md-
I am writing in hope to obtain permission to use a figure from your site. It is the figure for 'Q-angle' off the link on the patellofemoral overuse injury page: www.leadingmd.com/pate_orthowest/overview.asp. The purpose in which this figure would be used is for my Graduate thesis project on cycling, titled "Oxygen consumption: Effect of Pedal Width Variations Relative to Q-angle in Avid Cyclists".

If there is any protocol I must follow, please let me know. Thank you, I appreciate your time.

Sincerely,
Melinda J. McCutcheon
NMU HPER DEPT
Exercise Science Graduate Assistant
231-631-1159
mmccutch@nmu.edu

APPENDIX G

PERMISSION FOR USE OF PHOTOS IN FIGURE 4

Subject: RE: RE: Photos
Date: Mon, 30 Apr 2007 13:17:22 -0600
From: "Lee, Andy" <alee@usacycling.org>
To: "Melinda J McCutcheon" <mmccutch@nmu.edu>
Cc: "Smith, Andrea" <asmith@usacycling.org>

Melinda,
Thanks. I don't see a problem with those images as long as they are used strictly for the purposes which you requested. The image of Sheldon from the Bahamas should be credited to "Rob Jones/Canadian Cyclist". I took the one in Athens of Tyler, but you can just credit it as "Courtesy of USA Cycling"

Thanks
-Andy

Andy Lee
Director of Communications
USA Cycling
U.S. Olympic Training Center
1 Olympic Plaza
Colorado Springs, CO 80909
719-866-4867 (office)
719-231-2041 (mobile)
719-866-4596 (fax)
alee@usacycling.org
www.usacycling.org

From: Melinda J McCutcheon [mailto:mmccutch@nmu.edu]
Sent: Monday, April 30, 2007 11:34 AM
To: Lee, Andy
Subject: Re: RE: Photos

Thanks for the quick response Andy. The photos I had in mind are one of Sheldon Deeny from the 'Tour of the Bahamas' album (http://www.usacycling.org/gallery/album184/DSC0128), the other of Hamilton # '2004 Olympic Games' album. (http://www.usacycling.org/gallery/2004-Olympic-

Games/Olympic_Games_006). Let me know if there is anything else I need to use these. Thanks again Andy!

Melinda J. McCutcheon

Melinda,
That should be ok. Please let me know what images you were interested in using...

-Andy

Andy Lee
Director of Communications
USA Cycling
U.S. Olympic Training Center
1 Olympic Plaza
Colorado Springs, CO 80909
719-866-4867 (office)
719-231-2041 (mobile)
719-866-4596 (fax)
alee@usacycling.org
www.usacycling.org

-----Original Message-----
From: Melinda J McCutcheon [mailto:mmccutch@nmu.edu]
Sent: Sunday, April 29, 2007 6:40 PM
To: Mager, Mark
Subject: Photos

Dear Mr. Mager,
I am a graduate student at Northern Michigan University currently working on my thesis. I was interested in using some photos on your site of some racers in my write-up to illustrate some techniques. What are your rules on copy write photos? Of course you would be cited properly, but I didn't know if you had specific rules regarding the matter. Thank you for your time!

Melinda J. McCutcheon
Exercise Science Graduate Assistant
Northern Michigan University
mmccutch@nmu.edu
(231) 631-1159

APPENDIX H

PERMISSION FOR USE OF FIGURE 5

JUL-23-2007 05:08 LWW 2155218466 P.01/01

Wayne, Marie

From:	Melinda J McCutcheon [mmccutch@nmu.edu]
Posted At:	Sunday, July 22, 2007 11:07 pm
Conversation:	Requested Material
Posted To:	Permissions
Subject:	Requested Material

Northern Michigan University
Health, Physical Education, and Recreation Departmen
1401 Presque Isle Ave
Marquette, MI 49855

Melinda McCutcheon
mmccutch@nmu.edu
FAX: (906) 227-2181

Requested borrowed materials will be used as a diagram in a Masters thesis paper, titled- ENERGY ECONOMY: EFFECT OF LATERAL PEDAL WIDTH VARIATION RELATIVE TO Q-ANGLE IN AVID CYCLIST \. Paragraph in Lit Review where diagram will be used is discussing muscle action in cyclists.

Hamill, J. & Knutzen, K. (2003) Biomechanical basis of human movement Lippincott, Williams & Wilkins: Baltimore, MD p. 191- Figure of muscle activation during cycling phases.

Thank you!

Sincerely,

Melinda J. McCutcheon
Exercise Science Graduate Assistant
NMU HPER DEPT
mmccutch@nmu.edu
(906) 227-2541

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Marie Wayne date: 7/24/07
material must be original to our publication

1

TOTAL P.01

APPENDIX I

PERMISSION FOR USE OF FIGURE 6

Date: Sun, 30 Mar 2008 15:05:19 -0400 (EDT)
From: "Gregor, Robert J" <robert.gregor@ap.gatech.edu>
To: "Melinda J McCutcheon" <mmccutch@nmu.edu>
Subject: Re: Use of Figure

Melinda,

No problem.
Feel free to use that figure cited below.

Dr. Gregor

----- Original Message -----
From: "Melinda J McCutcheon" <mmccutch@nmu.edu>
To: "robert gregor" <robert.gregor@ap.gatech.edu>
Sent: Friday, March 28, 2008 12:05:35 PM (GMT-0500) America/New_York
Subject: Use of Figure

Dear Dr. Gregor,
I writing to inquire about using a figure from one of your articles in my thesis paper.

The article is: 10. 1994- Biomechanical Factors Associated with Shoe/Pedal Interfaces: Implications for Injury. Sports Medicine Journal 17(2): 117-131. Figure 7, page 129.

My project is titled: "Oxygen consumption: Effects of Lateral Pedal Width Variations Relative to Q-angle in Avid Cyclists". Your figure will be used in the literature review in the context of discussing cycling forces and output.

Sincerely,
Melinda J. McCutcheon
NMU Exercise Science Graduate Assistant

APPENDIX J

PERMISSION FOR USE OF FIGURE 7

Subject: RE: Permission for use of Figure
Date: Mon, 31 Mar 2008 07:46:09 +0100
From: "Atkinson, Greg" <G.Atkinson@ljmu.ac.uk
To: "Melinda J McCutcheon" <mmccutch@nmu.edu>

Dear Melinda,
That's fine by me.
Many thanks,

Greg

Greg Atkinson
Research Institute for Sport and Exercise Sciences
Liverpool John Moores University
Henry Cotton Campus
Webster Street
Liverpool L3 2ET, UK
Tel. +44 (0) 151 231 4249
Fax +44 (0) 151 231 4353
Email: G.Atkinson@ljmu.ac.uk

From: Melinda J McCutcheon
Sent: Sun 30/03/2008 23:41
To: Atkinson, Greg
Subject: Permission for use of Figure

Dear Professor Atkinson,
I am writing to seek permission to use a figure 1 from your 'Science and cycling: current knowledge and future directions for research' article. I am hoping to use it in the literature review section of my thesis project, titled: 'Oxygen consumption: Effects of Lateral Pedal Width Variations Relative to Q-angle in Avid Cyclists'. Thank you!

Sincerely,
Melinda J. McCutcheon
NMU Exercise Science Graduate Assistant