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The mechanical efficiency of bicycle derailleur and hub-gear transmissions

Chester R. Kyle, Ph.D.
Frank Berto

INTRODUCTION
Since human power provides the propulsion for a bicycle, losses in mechanical energy are far more important than if purely mechanical or electrical power is used.

The mechanical efficiency of a drive system is defined as the ratio of the power output to the power input in percent. Typically, automotive drive systems are from 90% to 99% efficient [1], meaning that from 1% to 20% of the energy input is lost in friction. A well-oiled straight chain-and-sprocket bicycle drive can be as high as 99% efficient [2]. With other types of bicycle transmissions, however, the range in efficiency can be similar to an automobile, that is from 80% to 99% [5-11]. In a bicycle, small losses can mean large performance differences—especially in competition [3, 4].

For example, suppose Boardman, the present holder of the bicycle world hour record (56.375 km), Manchester, England, 1986, were to use a bicycle with a drive that lost 2% more energy than his record machine. Boardman would travel almost 0.5 km less in one hour [3]. The hour record has been broken several times in the past 30 years by less than 0.5 km. If an Olympic 4000-meter pursuit team were to use bicycles that were 2% less efficient, they would be about 2 seconds slower in the 4000-meter team-pursuit race, which would have moved them from first place to fourth place in the 1996 Atlanta Olympics (4 min 8 sec vs. 4 min 6 sec) [4]. By using the wrong fixed gearing, differences of 2% are easily possible.

The editor and associate editors (you may choose with whom to correspond) welcome contributions to Human Power. They should be of long-term technical interest. News or to your local equivalent. Contributions include papers, articles, technical notes, reviews and letters. We welcome all types of contributions from HPVA members and from nonmembers.

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Contributions should be understandable by any Engineer who is familiar with the units used. They should be from Poland on aspects of the HPV scene there.

Your editor reviews some discussions on the future of HUMAN POWER.

Bicycle crank dynamometer, furnished by the USOC Sports Sciences Division

Previous published reports
There have been many published reports on the mechanical efficiency of bicycle transmissions during the past century; however, only a few have measured the efficiency using accurate mechanical means [1, 2, 5, 6, 7, 8, 9, 10, 11]. These studies found that bicycle drive efficiency depends upon many conditions such as load, chain tension, rpm, gear sizes, and the transmission type. As mentioned, the efficiencies varied from about 80% to 99%. The factors causing energy loss will be discussed in more detail later.

Mechanical methods of testing normally employ dynamometers that measure torque and rotational speed at the input and output of the drive system (with mechanical or electronic transducers). The combined energy losses in

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In this issue

The mechanical efficiency of bicycle derailleur and hub-gear transmissions

Al Taig has developed a lower-drag and cleaner alternative: using the impact (pitot) pressure picked up on the leading edge of the strut supporting the foil from the hull and controlling the attack angle from, e.g., a heelfoil.

PROJECT REVIEW
Chick2000 project team “Active Gals”
Mark Dearla reviews the report and video of a remarkable Japanese team that has achieved record performances with a talented woman pilot and an innovative plane. The wing uses a stressed-skin construction, allowing the main spar to be an I-beam and producing a “wing-tip deflection [that is] unamusingly small considering its low empty weight of 31 kg and its immense wing aspect ratio of 44.”

BOOK REVIEW
Richard’s 21st century bicycle book(s), by Richard Ballantine.
Your reviewer reviews two versions of the same book by Richard Ballantine: one in British English for the UK-European market, and one in American English for the North Americans. He gives two thumbs up.

LETTERS
Comments by Matt Weaver and John Stegmann on a paper in Human Power 51 on crank-arm length on recumbents, and responses by author Danny Too.

EDITORIALS
Marek Utkin writes a guest editorial from Poland on aspects of the HPV scene there.

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all drive-train components such as the heartbeats on city commutes, and derailleurs and derailleurs are usually included in the efficiencies. However, some studies recommend that high-speed, high-gear transmissions and to rapidly measure efficiency, the ergometer drive losses, so the actual reported efficiencies by 2 to 2.5%. The test fixture was then used to determine the rank order between each transmission at both variable load and constant load conditions. Bike racers can produce steady power outputs at 75 crank rpm. All chains were well oiled with light machine oil. Hub gears were usually left with their original grease lubricant, but this was regularly greased. The transmissions that were tested had the following gears.

Deerreul-type transmissions
4-speed automatic: Browning
This transmission has a gear layout similar to a standard derailleur system except electronically actuated gear segments in the rear cluster shift the chain up or down either automatically or manually. The Browning chain guide and tensioner, with its two jockey pulleys, has a similar appearance to a derailleur, and probably has nearly identical friction characteristics. It is however a passive follower. In this paper, the two Browning transmissions and the 27-speed derailleur transmissions will often be referred to as "derailleur-type" transmissions. The Browning chain drive for Browning Research, and it allowed rapid changing of front sprockets, chains and rear gears.

2. Bicycle-drive-train fixture
A special test fixture was built to mount a bicycle bottom bracket, cranks and chainrings, plus a rear hub without spokes or wheel. On the non-drive-side of the hub, a sprocket was attached to the hub which drove a Monarch bicycle ergometer wheel. The adjustable fixture was built by Jim Merz for Browning Research, and the data were stored for later analysis.

3. Monarch ergometer wheel
To measure power output, a Monarch aluminum ergometer wheel was driven in the test fixture by the transmission fixture through 36-tooth sprockets, one on the rear hub, and one on the front chainring. The flexibility of the chain and the chainring and rear cog. The chainring and a 16-tooth rear cog on the 2-speed cluster. The 2-speed cluster is well suited for today in Europe where they are used extensively on city commutes, and derailleurs are usually included in the efficiency tests. However, some studies recommend that high-speed, high-gear transmissions and to rapidly measure efficiency, the ergometer drive losses, so the actual reported efficiencies by 2 to 2.5%. The test fixture was then used to determine the rank order between each transmission at both variable load and constant load conditions. Bike racers can produce steady power outputs at 75 crank rpm. All chains were well oiled with light machine oil. Hub gears were usually left with their original grease lubricant, but this was regularly greased. The transmissions that were tested had the following gears.

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power outputs that are more than 100% to over 75% as the input power increases from 50 watts to 370 watts at 75 rpm.

Efficiency

The efficiency here is plotted in three ways:

1. Efficiency vs. power output

Here, efficiencies for all loads and power outputs are plotted. The peak efficiency was at 200 watts for periods of more than 150 watts unless being chased by rabid dogs. The results of the tests are shown in figures 1–14.

2. Average efficiency vs. gear number

Here, efficiencies for all test loads were averaged for each gear and the averages were plotted against the gear number. This curve shows the effect of gear ratio on efficiency under varying load conditions. For example, see figures 2, 6, 8, 10, or 11.

3. Average efficiency vs. load number

Here, transmission efficiencies for all loads were averaged for all gears and the averages were plotted against the gear number. This curve shows the effect of gear ratio on efficiency under varying load conditions. For example, see figures 2, 6, 8, 10, or 11. These curves provide the simplest way to compare transmissions.

Conclusions

By viewing the curves, several general observations and conclusions can be made:

1. Efficiency generally increases with the load—for all transmissions.

2. Figure 1, 4, 5, 7, 9, 12, or 14 all show this trend. Although this curve provides the simplest way to compare transmissions.

3. The tests show that some gears are inefficient.

4. Hub gears, such as the Rohloff 14, the efficiency no doubt depends on how many elements of the gear train are in motion as each gear is selected (see fig. 15). In the Rohloff, gears 3, 5, 7, 9, 11, and 13 have an average efficiency of 92.2%, while gears 21 and 24 have an average efficiency of 93.3%.

5. The tests show that some gears are inefficient.

6. The mechanical efficiency of bicycle transmissions is a function of the crank rpm [8]; therefore, the increasing gap is that the smaller sprockets (gears 9 and 12) have a lower efficiency. The two gears with the lowest efficiency of the 15 tested, both use a 12-tooth sprocket. The gears with 12-tooth sprockets (18, 24 and 27) have an average efficiency of 91.2%, while those involving 16-tooth sprockets (11, 20 and 25) have an average efficiency of 95.5%.

7. Dell’Oro and M. Malone. 1995. "Derailleur gains are reached by pulling on the control handle without any kind of mechanism. Other attempts will be made to explain this mechanism. It is obvious from the curves that the derailleurs (5) cannot be easily explained.

8. The test show that some gears are inefficient.

9. The efficiency decreases are reached by pulling on the control handle without any kind of mechanism. Other attempts will be made to explain this mechanism. It is obvious from the curves that the derailleurs (5) cannot be easily explained.


Figure 1. Shimano 3-speed (efficiency vs. load)

Figure 2. Sachs 3, Shimano 3, Sturmey 3 (average efficiency vs. gear)

Figure 3. Sachs 3, Shimano 3, Sturmey 3 (average efficiency vs. load)

Figure 4. Browning 4-speed (efficiency vs. load)

Figure 5. Shimano 4-speed (efficiency vs. load)

Figure 6. Browning 4, Shimano 4 (average efficiency vs. gear)

Figure 7. Browning 4-speed, Shimano 4-speed (average efficiency vs. load)

Figure 8. Rohloff 14 (average efficiency vs. gear)

Figure 9. Hub gear bicycle transmissions (average efficiency vs. load)

Figure 10. Browning 12 (average efficiency vs. gear)

Figure 11. Shimano 27 (average efficiency vs. gear)

Figure 12. Derailleur-type transmissions compared with hub gears (average efficiency vs. load)
**Technical Notes**

**Bicycle stability after front-tire deflation**

Dave Wilson (reporting partly for Soohyun Park)

We reported in Human Power, 51 (pp. 16–18) on experiments to provide steering stability after a front tire has deflated, there having been many reports of "flopping" instability that caused riders to be thrown off virtually instantaneously. We reported the tentative findings of Andy Oury, who increased the bead-seat diameter of so-called "drop-center" rims and thereby greatly decreased the tendency of deflated tires to "flop" from side to side. This past academic year another MIT undergraduate student, Soohyun Park, chose to do her BSME thesis on a continuation of this study. She first researched an improved bicycle model, resulting in the use of a IMX bicycle with a weight mounted on it representing approximately a rider's weight and center of mass. She found that over a wide range of weight values and positions the tire behavior when this bicycle was deceleration after deflation.

When this final step was taken the difference in performance changed dramatically. Flopping disappeared entirely, and the tire could provide safe and stable bicycle direction during the deceleration after deflation. These results therefore add to the previous somewhat tentative recommendation: that wheel and tire manufacturers and standards organizations should arrive at standards for the sizes and profiles of rims and of tire beads so that a fit tight enough to produce stable bicycle direction during the deceleration after deflation. There seems little doubt that many deaths and injuries would thereby be prevented.

--- Dave Wilson
<dgwilson@mediaone.net>

1. Cycle and motorcycle tires and wheel-rim standards. ETRTO, supplied by the Taiwan Bicycle Industry R&D Center, Taichung, Taiwan, 2001.
There is a better way than rolling
by Detlev Tschentscher

Human-powered vehicles on land usually have wheels. But there are attractive alternatives.

WALKING AND RUNNING AIDS
Humans are just ordinary mammals except that we have two legs, not four. Walking is easier than running, so all we need to do is to use only one leg, maybe leaving the other to support. Nearly every college in the U.S. has a track team. There is a better way.

There was no time for heat treatment to be ridden in the Argus Tour on 5th March 1982. The rim was made in dark bronze, and built a beautiful bicycle. During rolling, as well as during use and storage, the wheel was not stowed in an appropriate way, because the rim under size? I checked as much as I could, yet found no obvious reason for the failure. I therefore fitted a new tube using talcum powder to ensure that the failure. I therefore fitted a new tube using talcum powder to ensure that

Tire-rim compatibility
John Stegmann

Dave Wilson’s thoughts on the requirement of front-tire blowouts (Human Power, Fall 2000) reminded me of the pioneer work of C. S. Treadwell who did much a decade ago. When I commented to Dave that we had not considered that tire manufacturers might have difficulty in maintaining size standards, or that the wheel might be a subject of negotiations from front to back.

Chris Juden’s article, “The aluminium fork, based on information and encouragement from Dave, was the great inspiration. It provided the driving force: the interest of front-tire blowouts (Human Power, Fall 2000) reminded me of the pioneer work of C. S. Treadwell who did much a decade ago. When I commented to Dave that we had not considered that tire manufacturers might have difficulty in maintaining size standards, or that the wheel might be a subject of negotiations from front to back.

Figure 1. One of the illustrations from the Springerwalker U.S. patent document.

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Control of hydrofoils using dynamic water pressure
By Alastair ("Al") Tag

Hydrofoils are used on watercraft to provide lift, and/or stability. Generally, foils may be fixed or capable of varying their angle of incidence. Fixed foils may be angling to be part submerged, and part above the water surface, so that as they rise, the submerged area of foil decreases, and an equilibrium will be achieved. But foils which break the surface cause wave drag and suffer from "ventilation" (pulling air down over the upper surface of the foil due to decreased pressure). Thus, fully submerged foils, with some means to prevent them reaching the surface, are potentially more efficient.

Remedy
The remedy was twofold. First, we had the extrusion die altered very slightly, to broaden the head-seat groove to 2.5 mm. Five weeks passed before the new material arrived. Second, we had to ensure that the rim had no "lash" or play at all, so we tightened the rim very tight against the seat at about 80 N/m, and checked it daily.

Post Script
We had other difficulties, so the time delay between needing to beat the cost of imported rims and being able to manufacture it was almost two years. During that time the price of imported rims dropped significantly, aero rims manufacture was almost two years.

The 25-520 tires for the first wheel had wire beads. The 25-522 fold-up tires that blew off used synthetic fabric. We had only one other 622 tire. It had steel beads and worked well. We found that the tires with synthetic beads could be mounted on a larger rim than the wire beaded type. How this had happened we reasoned that it was not where our problem lay. Our problem had to do with the fact that synthetic beads could be mounted on a larger rim and mountain bikes arrived. IZIZI rims bent when he set the course record (which still stands) and three IHPVA world records, one of which still exists. The design lift-off speed can be used to find the proportions of the craft rises on the foils.

The position of the foil pivot in relation to the center of lift of the foil determines the forces required on the control lever, to increase the foil angle. It is advantageous to pivot the foil a small distance ahead of the lift center, so that the lift will act to reduce the foil angle. This is a stable condition and avoids any tendency for the angle (and hence lift) to increase uncontrollably. If the pivot is close to the lift center, the force required at the actuator will be relatively low and the size of the actuator can be minimized. This is important in order to reduce the volume of the air space in the foil (as shown in the diagram of the system). The reason a space is sealed in the pitot tube controls the rate of water pressure at the pitot, also acts on the actuator, but the effect is relatively small as the craft rises on the foils.

In this case:

\[
L = \frac{P}{p_{A}} \times (0.97V)^{2} \times \frac{1}{c}
\]

(5) can be used to find the proportions of the foil. The design lift-off speed can be used to determine the foil area, S, from eq. (1).

Pressure, p, for this speed is found from eq. (2).

Balance of Foil forces

A control force (P) acts on a lever of length \(L\) at a distance \(b\) behind the pivot, or moment center of gravity (MCG). The forces at the moment center of gravity (MCG) are balanced and is:

\[
Lb = Ph
\]

where \(L\) is lift, Newtons \(p\) = water density, \(s\) is area and \(v\) = smoothly a lift

If the foils, mounted on the tip floats, have a variable angle of incidence, they may be adjusted to provide variable lift, independently.

This could be done by manual control, requiring a skilled “pilot”, or by an automatic system which maintains each foil at a constant depth below the water surface.

Existing, state-of-the-art foil boats (such as the sailboats, Rovic and Hobie Tri-foiluser) use devices that follow the surface (a kind of water skier on the Tri-foiluser) connected by a mechanical link to the adjacent foil. These surface followers provides increased water drag, and are vulnerable to damage. Initially also raises the stress in the casing of a narrow, work fine with quite a shallow well.

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Remarkable achievement of ActiveGals HPA team in Japan
(from a communication from Toshiaki Yoshikawa)

This note gives some details of the human-powered aircraft "HYPER-Chick KoToNo Limited" built by the team "ActiveGals" in Japan, and sent by the team's leader Toshiaki Yoshikawa (letter, 20 March 2001). Mark Drela's review of the remarkable achievements of the team follow this note.

The technical data are shown in the drawing. The photographs show the team follow this note.

The CHicK-2000 human-powered aircraft by the ActiveGals group has a number of notable features.

The wing structure employs a stressed skin which provides the necessary torsional stiffness in addition to its usual duties of forming the airfoil contour. The most common approach has been to rely on a tubular spar to provide all the bending and torsional stiffness, with secondary foam sheeting and a thin Mylar wing skin providing the airfoil shape.

Using the stressed skin for torsion instead allows the use of a full-depth I-beam spar to provide the bending stiffness. The I-beam spar is a far more efficient bending member than the tube spar, and hence provides a stiffer and stronger wing for a given weight. Not surprisingly, the wing-tip deflection of the CHicK-2000 under load is amazingly small considering its low empty weight of 31 kg and its immense wing aspect ratio of 44. The high aspect ratio obviously contributes to the modest specific flight power of 3.6 W/kg pilot mass, despite a fairly high wing loading of 46 Pa which gives a rather fast cruising speed of about 8 m/s. Low power coupled with high speed gives the potential for large range, and also gives the ability to handle winder conditions more lightly-loaded HPAs.

One practical disadvantage of a stressed-skin HPA structure is that common construction materials such as polyethylene foam do not have a sufficient shear modulus for the task.

Review by Mark Drela

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One practical disadvantage of a stressed-skin HPA structure is that common construction materials such as polyethylene foam do not have a sufficient shear modulus for the task.

The ActiveGals group appears to have solved this problem with their fiberglass-reinforced styrene paper. The stressed skin is also very demanding of design details and construction quality to preclude local buckling or failure. Again, these problems appear to have been surmounted as the aircraft is clearly structurally sound. Construction photos reveal meticulous craftsmanship.

Other reported innovations include the use of aeroelastic effects to twist the wings for roll control. Judging from the type of control yoke, the pilot appears to have full three-axis control of the aircraft, although it is not clear how the wings are twisted in practice.

—Mark Drela, MIT professor of aeronautics and astronautics, Massachusetts Institute of Technology (principal designer and constructor of several MIT HPAs).
Above: A closer view of the cockpit and propeller of the CHicK-2000 aircraft. Right, Takashi Hattori, right-wing runner.

Human Power

Letters

Matt Weaver

Richard Too responds to two letters about his article (with Chris Williams), “Determination of the crank-arm length to maximize power production in recumbent cycle ergometry” (Human Power 51, Fall 2000).

Battle Mountain crank arms

In light of crank-arm length, I have a few observations on the recent article on bicycle cranks (by Danny Too and Chris Williams). It took me a moment to deduce what was actually tested, but if cranks are of any interest to you, I find it important to note and relay the following.

1. The test was a variable-rpm, “fixed-torque” test: relatively light pedal force, proportionately lighter for longer cranks; riders “gave their all” (maximum exertion) for 30 seconds. Cadences reached high rates (>170 rpm) for the shortest cranks, and modest rates (135 rpm) for the longest cranks; cadences dropped to the low 80 rpm for short cranks, and low 96 rpm for longest cranks in the final five seconds. Calculated power output was proportional to cadence: the faster you can spin, the more power you get (fixed torque, and flywheel inertia ignored).

2. The torque decided upon was referred to as the “appropriate load” or “85 g/kg of subject body mass” (apparently total mass, not lean or leg-muscle mass).

3. I’m not sure what “appropriate load” is, but it can be deduced. The apparatus was as follows: a 52/14 single-gear chain drive to a flywheel with a 1.615-meter circumference, with a friction belt of known net tension wrapped about it. That’s roughly a 0.5-meter belt for the shortest cranks, which cadenced dropped to the low 80 rpm for short cranks. I would say this is not the best choice for moving the belt-force distance of 0.6 meters for every revolution of the crank: effectively a fixed-mean crank torque = 0.6 N m per total rider body mass (0.27 ft lb per pound total rider weight) (ignoring flywheel inertia).

For example, for me (“85 g/kg” belt tension mass, and 98 lb rider body mass, 175 mm crank): belt tension = (0.27 ft lb per pound total rider weight) (ignoring flywheel inertia).

Richard has been more dedicated and more successful. The books differ mainly in the use, respectively, of American English and British English, including some translations of slang. Some examples slipped through. For instance, how many American readers would know what to expect if an HPV were classed as “dodgy”? (Roughly it means that it wouldn’t be a good bet.)

The British version of the book has, as the sole representative of cycling on the front cover, Richard’s daughter in a carbon Windscheetah tricycle HPV with a lot of advanced components. We must give Richard some of the credit for the publisher’s belief that a bike book with an HPV on the cover was not going to put people off buying it. The U.S. publisher, The Overlook Press (Woodstock and New York), apparently felt that doing this in North America would be too risky, and I think that many of us would agree, with some sadness.

Inside the books have many similarities: there are 22 chapters having the same titles, starting with “Get a bike!” to “Done!” All the chapters are written with a breezy enthusiasm coupled with a deep knowledge of the field and an instinct for telling people, from the raw beginners to seasoned enthusiasts, what they want to know.

Of particular interest to HPV members is chapter 5: “Zzzwaaaammmon!” (27 pages devoted entirely to extolling HPVs, and, on a quick scan, having more illustrations than any other chapter. That alone sets Richard’s book well apart, i.e., well ahead) of all competitors.

You will enjoy this book. The British version has the ISBN number 0 330 37717 5; it costs UK£16.99. The North American version has ISBN 1 58567 112 0. I bought my copy from the Overlook Press, Lewis Hollow Road, Woodstock, NY 12498; for US$28.50 including P&P; the bookstore price should be about US$18.00.

—David Gordon (Dave) Wilson
dgordon@mae.ucla.edu

Richard’s 21st CENTURY BICYCLE BOOK(S) by Richard Ballantine

reviewed by Dave Wilson

This book is two books, or one book in two versions. One is for non-North American readers; and was published by Pan Books (Macmillan) in Britain at the end of 2000. Earlier editions came out in 1972, 1975 and 1988. It is a very successful book: one of the messages on the cover states...”the best-selling bike book of all time, with over one million copies sold?” As I wrote this I was about to leave for Norwalk, CT, for the June first launching of the North American version with the author himself.

Before I wax too enthusiastic about the book(s) I should confess my biases. I first met Richard Ballantine in 1980 in Bremen, Germany, at a bicycling conference called “Velo-City.” I had brought along one of the first Avatar 2000s, which received a great deal of favorable publicity. (We hadn’t patented it, just made a prototype, which was rather illegal.) We must have sold several rather favorable publicities. (We hadn’t patented it, just made a prototype, which was rather illegal.)

In 1977, I bought an Avatar, and put it (with a carbon Windscheetah tricycle HPV with a lot of advanced components) in the front cover, Richard’s daughter in a carbon Windscheetah tricycle HPV with a lot of advanced components. We must give Richard some of the credit for the publisher’s belief that a bike book with an HPV on the cover was not going to put people off buying it. The U.S. publisher, The Overlook Press (Woodstock and New York), apparently felt that doing this in North America would be too risky, and I think that many of us would agree, with some sadness.

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4. Test starting rpm (at t=0) is not given, however long cranks are believed to flywheel was accelerated until "inertial resistance had been overcome."

5. Energy supply anaerobic would most likely suspect that if a sufficiently high "appropriate"-load torque were chosen, the experiment observations would reverse, with the longer cranks supe-

6. Consequently lower peak power. In my opinion, Mr. Weaver is correct in that the experimental observations would reverse to a more "superior for peak power." In fact, this is what has been observed, based on the data I collected on females, examining the interaction between crank-length, load, and power output in the same recumbent position. Females were selected because they are not as heavy (nor anabolic) as males. The peak load used and tested (165 gm/kg BMI) were within the maximum load capac-

7. Measuring the cadence remained fixed at its set value (152 mm) for a "healthy" human. I have not yet incrementing workload until exhausted. I have yet to randomly vary (as would height and proportions) that will maximize power production and minimize fatigue that is important. The reason is because (1) many others have researched into the correlation between crank-length and leg-length/proportions that is impor-

8. Shorter the crank, in comparison with the rider's leg, the more closely does the rider's leg configurations? I now wonder if they do not believe it the leg length or leg-length proportions that is impor-

9. Cyclists (have/always) imagined that leg length (or femur length) be an interaction between crank-length and leg-length/proportions. However, there is a theoretical basis for why shorter cranks would favour higher power output and to time to exhaustion, when different crank-lengths are analysed (or the selected crank-length can be incremented and increasing workload until exhaustion (or when the selected cadence can no longer be maintained). I have yet to analyzed the data or the trend associ-

10. Bike hub and get to know of contracting muscles, there is/are some joint angles (hip, knee, ankle) that results from an inter-

11. Some crank experiments: In my garage in 1995 I prepared some tools to discover such basic information. I built a computer-controlled cadence tester to explore my 152-mm cranks. Cadence was manipulated by digital feedback control to an electromagnetic brake, and instantaneous torque/crank angle via a trol to an electromagnetic brake, and translated precisely by digital feedback control con-

12. The actual exercise as it relates to cycling: I would not conclude in any way that short cranks are preferred for peak power, I would not conclude in any way that long cranks are better. I agree that the experiment was not designed to cover many events (especially based on a brief 30-second maximal and large cadence production). With fatigue state of muscles" and that the near-circular motion produced with different combinations of leg length and leg-length proportions interacting with different crank-arm lengths. However, there is a theoretical basis for why shorter cranks would favour higher peak power output, as the crank-arm lengths in the study varied exception-

13. The terrain length and leg-length/proportions (as well as other anthropometric data) on the study, and even if we did, that would be a different topic and study altogether, (2) discussion of leg lengths and proportions would have detracted the reader from the "most" and trends found in the study, (3) leg lengths/proportions would have been expected to randomly vary (as would height and proportions) that will maximize power production and minimize fatigue that is important. The reason is because (1) many others have researched into the correlation between crank-length and leg-length/proportions. However, there is a theoretical basis for why shorter cranks would favour higher power output and to time to exhaustion, when different crank-lengths are analysed (or the selected crank-length can be incremented and increasing workload until exhaustion (or when the selected cadence can no longer be maintained). I have yet to analyzed the data or the trend associ-

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optimal joint angles to maximize cycling performance have not been determined yet because of the difficulty in manipulating, reproducing and then systematically manipulating, the joint angles with subjects of different leg lengths and leg-length proportions. Even if the range of joint angles were determined, to obtain these optimum joint angles may result in crank-arm length being systematically manipulated because a change in crank-arm length affects both the hip and knee angle simultaneously. This makes it very difficult to determine whether changes in power performance when manipulating crank-arm length is primarily attributed to changes in hip angle, knee angle, or both (the net effect of this interaction) especially since this involves multiple joint angles acting on multiple joint segments simultaneously.

Stegmann: "Cyclists have (always) imagined that their leg muscles would double (short femurs?) will be happier with short crank-lengths and long cyclists with long cranks. The cyclists used for the test varied in height from 1.72 m to 1.88 m, and there must surely be the possibility of greater variance in the leg-length configurations?"

Stegmann: "I wonder if there is enough variation in their leg configurations. But again, it is probably not the actual leg configurations that is as important as the leg configurations that result in the hip, knee, and ankle angle that will maximize power production when manipulating with some crank arm-length combinations for subjects of the same leg length with different leg-length proportions, or of different leg lengths with same leg-length proportions. This would imply (and possibly conclude) that the optimum crank-arm length is very individualized, and dependant, on both the leg length and leg-length proportions of the cyclist (in addition to other factors such as pedaling rate and load). This would not be a very satisfying answer since it is essential to have a simple solution to a very complex problem. In some of my previous investigations, I was able to manipulate hip angles (and observe the changes in cycling performance), while maintaining the same knee angle (and helped explain why power output in different leg-length positions is greater than in upright cycling positions). We have also examined the effects of changing hip to pedal distance on joint angles and on power production (which we will be submitting to Physical Education & Sport publication). However, this interaction between hip and knee angle to maximize power production is probably more complex when crank-arm length is systematically manipulated because a change in crank-arm length affects both the hip and knee angle simultaneously. This makes it very difficult to determine whether changes in power performance when manipulating crank-arm length is primarily attributed to changes in hip angle, knee angle, or both (the net effect of this interaction) especially since this involves multiple joint angles acting on multiple joint segments simultaneously.

Stegmann: "I now wonder if there is evidence to support this critical observation. In an early Archbold Scan (Bicycles & Tricycles, p. 266) considered the speed and motion of the cyclist's knee joint and wrote: 'The shorter the crank, in comparison with the rider's leg, the more closely does the motion of the knee approximate to simple harmonic motion; with simple harmonic motion the curve is a circle.' From this it would appear that the near circu- lar motion produced by shorter cranks would favour higher pedaling speeds. I don't know if there is evidence to support this notion merely because I would argue that shorter cranks would favour higher pedaling speeds (if only because the pedal loads are used). However, as the pedal loads increase (and continues to increase), the pedaling speed (at some point) will start to decrease. At this point, longer cranks would be favored to minimize fatigue and to maximize power output. If you are interested, we have published a paper with (data involving upright-cycling-ecology that included a discussion on the relationship between action between crank-arm length and pedaling rate, and its effect on the kinetic and quasi-static moment contribution to the total joint moments to the moment production component of the minimum. The reference for the paper is: Too, D. & Landweer, G. E. (2000). The relationship between hip angle on joint length and power production in upright-cycling-ecology (Journal of Sports Science)."

Stegmann: Plotting the Torque: Williams MAXPED and MINPED figures from Table 1 on the graph in Figure 2 (p. 4), using a scale of 1000 W=145 rpm, the Power and rpm curves are almost a very close match between MAXPED and MINPED from Table 1 with Peak and Minimum Power from the graph in Figure 2, since MAXPED and MINPED were determined from the Newtonian resolu- tions for a 5-sec interval, as was Peak and Minimum Power (which was then used for the very simple equation equal for Peak and Minimum Power).

The curves may be used in the study exceptionally far more than the cyclist's legs. Yes. The crank-arm length was deliberately selected so that it would vary exceptionally far more than the bicycle's legs. Why? The reason? We wanted to examine the range of crank-arm lengths that could possibly be used (and a few in between), in order to determine the trend in power production/output with increasing crank-arm length.

Stegmann: Yet, the facts show that shorter crank allowed higher rpm, and higher rpm produced greater power. Yes, that statement is correct, but only for the load used in that study (85 g/kg of each subject's body mass), since there is an interaction between pedal load, rate, and crank-arm length. If the load is increased and con- tinually increased, at some point, pedal- ing rate will decrease resulting in a dec- rease in power. At this point, longer crank-lengths would be more active in producing power. I have data to support this, and will be submitting a paper to a journal in a future issue of Human Power."

The future of HUMAN POWER

This heading is deliberately ambigu- ous to reflect the many choices of the future, as to the journal. There are discussions underway on a new basis for the inter- national association, and therefore for this journal. Here is a concise summary of the present position just written by Richard Ballantine, Editor of this journal in active part in trying to ensure a healthy continuation of both. The IBHPA was founded as a US- based organization in 1975. HPVs from other countries joined the IBHPA as chapters, of equal status with chap- ters based on US states or regions. Over time, the non-US clubs grew in size, and became independent, auto- nomous chapters, and an international organization that was truly democratic rather than US-dominated.

"Following the Leicester Declaration in 1986/86, the IBHPA was reorganized in 1987. In 1990, and as a result, the North American HPVs from other countries became autonomous, and a new IBHPA was formed, comprised of representa- tives of clubs and groups from various countries. Yet the work of the IBHPA, which is the responsibility of the mem- ber clubs continues and would be performed almost exclusively by North American HPV members, who do the recordkeeping, maintaining the web site, and produce Human Power, all on a volunteer basis. At the Brighton meeting in 1999, the IBHPA representatives agreed that this cannot go on – other IBHPA member countries need to do their fair share of the work.

"The US IBHPA representative, Paul Gracey, raised this matter in a recent report to the IBHPA Board. "The one aspect of the IBHPA that is ongoing day-to-day and seems to me to be under-appreciated is Web and Internet services. Our visibility to the world is embedded in those services located in the headquarters in New York, the Amer- ican Power. Like everything else that is related to the Internet, the bloom of newness may be fading, but this may at some time need to be put on a compensated basis. Thus, and the calls for records reports and other archival materials is the major reason it may yet be desirable to try to establish a physical and web site for the endorsement to see its care."

Voluntary submissions to Human Power