Elements of the Chad Hedrick Double Push

c. P. J. Baum, November 2001.

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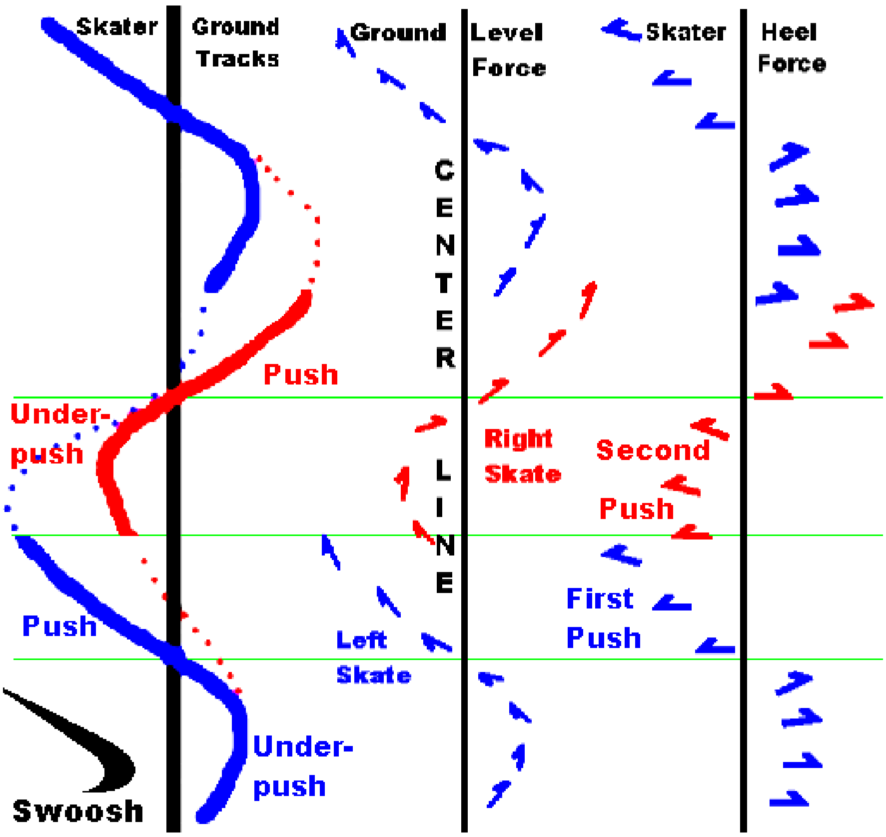
Introduction

Some clarification of the Double-Push skating technique is presented here and some paradoxes are resolved. This discussion is based on analysis of video clips from Doublepush.com (1) taken while Chad Hedrick was performing his Double Push. An example of that stroke is shown in the animation below and to the left. The figures to the right of the animation are the ground tracks obtained from the video and my interpretation of the forces involved. Discussions of skating usually refer to a straight line indicating the direction of motion variously called a mid-line (2), the direction of classic glide (3,4), or the Center Line as I call it here (the solid black line in the drawings below). The arrows on the right-side top panel show explicity the two pushes in the double push. The pull forces are not drawn but I will discuss them briefly later on.

Observing Chad above, no part of his body is stationary. The upper body and mid body lean left and right so they will trace out a sinusoidal curve and not a straight line. But we can average over any set of such curves and get a straight line centered between the left and right extremes. This straight line will be called the Center Line here.

In the animation above Chad is, of course, skating out of the screen while in the figures to the right he is moving from the bottom of the screen to the top of the screen. So Blue will represent his left skate and Red will be his right skate.



Looking at the leftmost track figure above we see an underpush and then a push on the left skate (these are the 2 pushes of the double push in Matzger and Burger's view). I do not see much of their "arcuate banana", preferring to see a rotated Nike Swoosh instead. Looking at one foot only, the underpush precedes the push and this is how Matzger and Burger present it. I prefer to look at one side of the center line at a time and then you see first a push on one foot and then an underpush on the other foot.

Matzger and Burger's underpush begins exactly on the center line but Chad's version here begins the underpush slightly over the center line (The skate is set down nearly under his head but his head is also over the center line at that time). Now Barry Publow's Double Push (2) had both skates on the ground simultaneously for a period while Eddy Matzger and Dan Burger drew both skates off the ground for a fraction of a second (presumably a glitch in their drawing). Here Chad looks to be setting one foot down at the instant the other lifts off the ground.

From the picture I am proposing here the "push" is the first push and corresponds to the classic single-push (done on the inside edge on the wheel). Then the "underpush" becomes the second push (on the outside edge). So there is an instantaneous weight transfer from the outside skate to the inside skate. While this much is similar to other versions of the Double Push, there is also a (sideways) momentum transfer from skate to skate. This point will be discussed more later.

Forces in the Double Push

The Push/No-Push Paradox

As I pointed out in an earlier analysis (5), Chad's ground tracks (video time trax) showed no evidence of a push force when examined quantitatively. But it is very rare to find a skater who does not believe that the Double Push contains a push force. So what is going on?

I think the resolution of this paradox lies in understanding how the cameraman chose to film the double push. Specifically, the camera was placed in a truck traveling at a fixed speed and Chad was invited to pace the truck from behind it. So both the camera and Chad are moving at constant speed or zero acceleration. Consequently the net force on Chad is zero and Chad adjusts his stroke continuously to maintain this state of zero acceleration. If Fs is the skater's biomechanical force and Fd is the mechanical drag force then the situation becomes:

$$Fs + Fd = 0$$
or,
$$Fs = -Fd$$

So the skater's push force is exactly cancelled by the drag forces. Now if you claim that Chad is doing a "double push" (with push force Fs), then you have to also accept that the drag forces (-Fd) are doing a "double un-push" with the result that there is no net push at all. The fact that Chad's skates move left and right of the center line proves that he is doing a double-excursion but does contain much (easily obtainable) information on the double-pushes. According to the formulas above we need to know either the drag forces or the skater's force directly in order to say much about the pushes. When you consider that the drag forces include wind drag, rolling resistance (6), edge resistance (7), and turning effects you see that this is not a very appealing approach. Consequently I will rely on an earlier skater modelling effort (8) to estimate the ground level forces applied by the skater.

Ground-Level Forces

The mechanical ground force really has five components (one for each of the five wheels on a skate). And none of these five forces will have the same direction or magnitude except under special circumstances. But to start off with we can imagine that the directions and magnitudes are averaged down to one mechanical force. But in the next section where the skater's biomechanical force is discussed one has to imagine that the front wheel(s) forces are averaged into one mechanical force while the rear wheel(s) forces are averaged into a second biomechanical force.

No one I know has measured the ground level mechanical force for an inline skater doing the double push so I will extrapolate from a skater modelling effort (8) to estimate the ground level forces. These ground force vectors are drawn as red and blue arrows in the middle panel of the top figure on this page. The point here is to show that there is always a forward component of the force which will accelerate the skater forward.

At the transition between the First Push (Push) and the Second Push (Underpush) (labelled on the right-most panel of the top figure) there is a smooth transition and the skater accelerates seamlessly.

Ankle-Level Forces

As mentioned earlier when we get up to skater-level it is necessary to break out the biomechanical force which the skater develops from the mechanical force which the skater controls. So on the right-most panel above there are really two forces, the first being the mechanical cornering force at the front wheels (toe) and the biomechanical push force at the rear wheels (heel). If there were only push forces the skates would never return across the center line and the double push would fail. So the cornering pull forces are essential.

The pull force is generated in the contact patches of the front wheels. This force, *which is perpendicular to the direction of expected roll*, was called the edge force (9) and there is an analog for car tires called the camber force (10,11). By allowing gravity to act preferentially at the toe and the skaters's biomechanical push force to act preferentially at the heel the skate is powered around a corner rather like a rear wheel drive car. i.e., the steering is at the front, the powering at the rear and the rear wheels follow the front wheels around the corner.

Higher-Level Forces

Viewing the animation at the top of this page confirms that the first push is characterized by significant leg extension. However, the second push shows no such extension so we must look elsewhere for the power source of the second push. On a previous page (8) I suggested an inverted pendulum mechanism for powering the second push. The pendulum-like lean is clearly evident in Chad's motion. Notice that I call it a lean and not a fall because a fall seems to imply that it is gravity driven and gravity accelerates downward and not forward. While there is ample evidence for a single inverted pendulum here, the powering mechanism proposed used a double inverted pendulum which would be powered by lateral flexion. Now the animation shows only the slightest hint of lateral flexion and I think the reason it is not more evident is again because he is skating at constant speed or zero acceleration. So as soon as Chad begins to develop power through lateral flexion it is delivered to the skates as the lean during the underpush undoes the effect of the lateral flexion.

So I would attribute the first push to leg extension as in the classic single push. However, the second push has three components:

1. Momentum is transferred from the outer skate to the inner skate so the first push initiates the second push at the instant of weight transfer.
2. Lateral flexion continues to power the underpush through the double inverted pendulum mechanism.
3. Torsional flexion rotates the midbody and drives the heel around the corner and back to the center line completing the second push.

While the first push seems to be accomplished by lower body (leg) muscles, the second push relies on midbody muscles for power. In particular, I consider that this power mainly derives from the lower back muscles. Consequently it would involve two engines (one leg at a time and the midbody muscles) during a stroke. In this sense this skating technique satisfies the definition of double push I gave earlier (12).

Discussion and Conclusions

In terms of unfinished business the matter of stroke classification arises. While Chad here uses a stroke which abruptly changes from one skate to the other (no overlap of one leg with the other and no "underlap") there are other cases where there is some overlap and more work needs to be done to work out the nomenclature for these kind of strokes. There are skating styles where none of the terms single, double, or triple push seem appropriate.

While the classic style is somtimes called "stroke and glide, the double push seems to be a "stroke and understroke". This emphasizes a fundamental difference between the two: there is no power developed in the classic skate glide phase but there is power developed during the underpush. So the double push powers continuously and we can say is has a "duty cycle" of 100%. However, the classic stroke has a somewhat lower duty cycle because of the glide phase. This seems to be equivalent to the usual observation that the double push has a wider stroke than the classic style because of the added underpush.

It appears that the real advantage of the double push lies in the use of an additional set of muscles during the underpush which are not used in the classic single push. But the use of the midbody muscles to power the underpush means that the skater tends to stand up higher than the classic position and he becomes subject to more wind drag. So there seems to come a speed when it may be necessary to move back toward classic to drop the high speed drag.

References/Footnotes

1. 1 Doublepush.com
2. 2 Barry Publow, Inline Evolution: The Changing Face Of Technical Character, Speed Skating Times, Aug/Sept 1966, p.
3. 3 Eddy Matzger and Dan Burger, Dan's Double Push Stripped Bare, Fitness and Speed Skating Times, Early Summer '99, p. 10.
4. 4 Burger et al. DP site
5. 52fullyeff.html#ChadTimetrax
6. 6rollloss.html
7. 7edgeloss.html
8. 81fullyeff.html
9. 9 Turning2.html
10. 10 http://www.ctv.es/USERS/softtech/motos/Prog_Manual.htm (The science of cornering Users Manual, Sept. 1999). It concludes-- Camber force coefficient: This is a property of the tyres and it relates the lateral force (called camber force) generated to the lean angle of the tyre and the vertical load (weight) acting on it. This varies with tyre type and construction and is broadly within the range of 0.5 to 1.8.
11. 11 Karl Niklass, Private Communication, September 2001.
12. 12 secondpush.html

Click to go back to the *INDEX*
