Armstrong's published physiological data fails to explain his Tour de France successes
-Armstrong's 71.5 ml/kg/min maximal oxygen uptake (coinciding with his highest reported mechanical efficiency in November 1999) is less than the *average* of 78.8 ml/kg/min reported in a typical team of 24 professional cyclists (Mujika and Padilla 2001)
-his highest recorded maximal oxygen uptake is also less than the highest found in a typical team of professional cyclists (Mujika and Padilla 2001)
-rather than being exceptional, Armstrong's peak lactate of 6.5-7.5 mM is within the range previously reported in professional cyclists (Mujika and Padilla 2001)

The paper breaches accepted scientific principles
-the paper abrogates fundamental scientific practice by deriving results of power-to-weight from hearsay rather than measured data
-the author failed to measure body weight at the Tour de France, therefore all claims of an 18% improvement in power-to-weight during Tour de France victories are unsubstantiated and unreliable.

Photographic evidence casts doubt on the scientific veracity of the paper
-a 1992 photograph appeared in a prominent cycling magazine of the author testing Armstrong who was riding his own bicycle, rather than the Monark ergometer that the author claimed he was always tested on
-conducting baseline testing on a different ergometer to subsequent tests makes all longitudinal comparisons invalid

The paper lacks internal validity
-virtually all of the improvement in mechanical efficiency, which the author proposes was induced by intensive endurance training, was also present during a period of dramatically reduced training (7.0% improvement August 1997 after reduced training, 8.8% improvement November 1999 after intensive training). This means that any improvement in mechanical efficiency, if present, must have been due to some mechanism other than training.

The paper lacks external validity
-the authors attribution of success to an improvement in mechanical efficiency is inconsistent with performance data from Armstrong, who won the 1993 World Road Racing Championship at a time when mechanical efficiency showed no notable improvement, yet he placed only 4th in the 1998 World Road Racing Championship after a 7.0% improvement in mechanical efficiency had been reported.
-improved mechanical efficiency was also disassociated with Tour de France success, since Armstrong failed to finish the 1998 Tour de France with mechanical efficiency 7.0% greater than baseline, but won the 1999 event with values that had increased only marginally more to 8.8% above baseline.

The study design appears to lack validity
-an eyewitness to the first test session recalls that Armstrong rode directly to the laboratory following several hours of cycling in surrounding mountains with a team-mate, which fails to control for the confounding influence of prior exercise on test results. This

significant flaw in baseline results precludes a valid comparison being made to any subsequent test results, and subsequently any claims of improved efficiency.

The author failed to provide in the paper, nor in subsequent scientific letters, any longitudinal data on the accuracy and reliability of testing equipment (both ergometer and gas analysis equipment)
-the author used a prototype ergometer that underwent major modification by an unauthorised agent, which prompted the manufacturer to disclaim any responsibility for the accuracy of that ergometer.
-when basing conclusions upon longitudinal test data collected over a 7-year period, it is a pre-requisite to provide accuracy and reliability data that span the collection period.

Contrary to the author's claim, the study design appears to be 'opportunistic' rather than a study of change in muscle efficiency (or maturation)
-no muscle efficiency data was collected in September 1993, which contradicts the stated aim of the paper
-3 of the 5 collections occurred in the first nine months of a 7-year study which casts serious doubt on the author's claim that the goal was to 'observe maturation'
-on one hand the author heralds the noteworthiness of the paper because the subject eventually became a six-time winner of the Tour de France, yet inexplicably the author did not report any data after the rider had become a multiple winner (and in so doing distinguished himself from all previous Tour de France winners)

Serious questions raised about the veracity of the paper
-photograph of Coyle testing Armstrong on a Schwinn ergometer, which is categorically denied by Coyle in each of two responses to published scientific letters which raised concerns on the issue of whether Armstrong was tested on the same ergometer over the entire 7-year period

Coyle speculates that the increase in efficiency was due to an increase in the percentage of Type I fibres from 60 to 80%
-such a change has never been documented to occur in humans
-even Coyle acknowledged in his 1992 paper that training per se is unlikely to cause such an increase (or else he would have expected to see "some manifestation of improved skills" which was not the case).

Details of critique for expert testimony

Gaesser and Brooks (1975) Figure 4
-shows that increased pedalling speed results in decrease in efficiency
-this suggests that Armstrong's increase in cadence referred to by Coyle would erode any benefit of improved muscular efficiency
-this supported by Siddossis, Horrowitz and Coyle (1992) at the time Armstrong was first tested, who showed that gross efficiency tended to be lower when cadence increased from 80rpm to 100rpm
-however no difference found by Marsh et al (2000)

Gaesser and Brooks (1975) p1137
"The gross efficiency calculation apears to be of little value in determining muscular efficiency. It "indicates little of the potentialities of the human body for severe muscular work, and gives no conception of the possible efficiency of the human body as a machine"

Passfield and Doust (2000)
-showed that ~60 min of moderate-intensity cycling decreased gross efficiency by 8%
-demonstrates that if Armstrong was cycling in Austin mountains immediately before Nov 92 test this in itself could account for the 8% reported improvement from 92-99.
-Lucia (2000) demonstrated that the increase in oxygen consumption (ie decrease in efficiency) associated with exercise also occurs in professional cyclists

Reliability of efficiency measures
-Mosely (2001) showed that the within-subject CV for DE was 6.7% (95% CI was 5-10%) which exceeds the 8.2% reported by Coyle between 92 and 99, suggesting that a 8.2% difference could be the result of random error and not a real change.
-Mosely (2001) showed within-subject CV for GE was 4.2% (3.2-6.4%) which approaches the 8.8% reported by Coyle
-Mosely study was optimised to assess reliability (no exercise day prior, calibrated ergometer, same gas analysis equipment)

Deposition outline

Armstrong's published physiological data fails to explain his Tour de France successes
-Coyle's Discussion includes reference to a "remarkably high VO2max of ~6.0 L/min" which he states remained relatively stable
-stability is questionable, given that it only reached a level of 6.0 L/min once in 7 years, and the remainder of the time is was subsantially lower within the range 5.5 to 5.8 L/min
-his highest recorded maximal oxygen uptake is also less than the highest value of 6.4 L/min found in a typical team of professional cyclists (Mujika and Padilla 2001)
-also lower than the 6.24 L/min recorded in an Australian track cyclist (Jeukendrup 2000)

-as Coyle recognises, cycling is body weight dependent especially on mountain stages so the relative oxygen uptake values are the most relevant
-we see Armstrong's 71.5 ml/kg/min maximal oxygen uptake (coinciding with his highest reported mechanical efficiency in November 1999) is less than the *average* of 78.8 ml/kg/min reported in a typical team of 24 professional cyclists (Mujika and Padilla 2001)
-the 1987 TT Champion measured in Coyle's own lab had values comparable with Armstrong (show data)
-an Australian track cyclist displayed values of 80 ml/kg/min over a 6 year period, peaking at 88.2 ml/kg/min (Jeukendrup 2000)
-two subjects in Lucia (2002) have values of 82.5 ml/kg/min and 82.3 ml/kg/min, the latter a specialist climber who could only manage a Top 10 finish in Tour de France
-Lucia (2000) found n=8 climbers with average VO2max of 78.6 ml/kg/min
-see that Table VIII of Faria (1995) dispels completely the notion that Armstrong's relativel maximal oxygen uptake was unique

Coyle refers to an "extremely low" peak lactate concentration
-use of PCA method conflicts with accounts from staff who instead remember a YSI analyser being used to calculate values
- the most recent review of lacatate metabolism in cycling clearly noted that contrary to the traditional view, every aspect of lactate metabolism is beneficical and should not be viewed as a negative facet, and that it was better to conclude that high lactate levels are not detrimental to cycling performance
--puzzling why no lactate data or lactate thresholds were presented after the subject had recovered from cancer...(only reduced training values)
-rather than being exceptional, Armstrong's peak lactates of 6.5-7.5 mM are within the lower limit of the range previously reported in professional cyclists (Mujika and Padilla 2001)
-Lucia (2000) shows that peak lactates for top climbers and time triallists were between 5 and 7 mM
-such values have also been found in Australian mountain bike riders (Lee et al. 2002)
-Gnehm (1997) reported range of 5.6-12.0
-Padilla (2000) range 6.9 – 13.7

Coyle conjectured that there was an 18% improvement at each TDF based on his speculation that Armstrong's body weight was 72 kg when he competed (and assumed he maintained his VO2max of 6.0 L/min)
-body weight was 79kg before cancer, it was 80 kg after cancer, and it was 80 kg four months after the 99 TDF victory
-during this time data shows that his muscle mass was about 70 kg from 1992-1999 (ie about 10 kg of body fat)
-infers that at the TDF when his body mass was 72 kg he had no more than 2 kg of body fat, which represents a percentage of 2.8% which is incomprehensible (lowest recorded for road cyclists 5.9%, or 4.8% in mountain bikers, Lee et al 2002)
-Fernandez (2000) range for pro cyclists was 6.5 to 11.3%

Unclear why Sep 93 data do not include efficiency
-nor clear what 'corroborated by USOC' means
-where were these data collected???

Coyle acknowledges that "because success in TDF is typically determined when cycling uphill on mountains, it is best to normalize power to body weight (ie W/kg)"
-at such times cyclists are operating near maxium, purportedly at power outputs approaching 500W
-why was no such peak power output data reported for Armstrong?
-a strange omission from a paper that takes the trouble to report peak oxygen uptake, peak heart rate and peak lactate values, as well as power outputs at a VO2 of 5.0L/min

Efficiency is a far from exact science
-several interpretations as to what it is in fact measuring (gross, work, delta, etc)
GE has been roundily criticised as being invalid (Goesser and Brooks) *INCLUDE COYLE PAPER
-apparent that despite strenuous efforts to standardise measure, the changes found in Armstrong have been found to occur within a 2-3 week period (as a result of measurement error alone, see Mosely data)
Delta efficiency more widely accepted, but it is difficult to measure
-CV of 6.7% (5-10%) which indicates that the 8% difference reported by Coyle could be nothing more than experimental error or 'slop'
-underlines the need for careful calibration of gas analysers and ergometer
-however there was no reliability data presented in the original paper, and the data offered in subsequent scientific letters was extracted from a 1994 doctoral thesis (it is self-evident that reporting precision of gas analysers in a 1994 cannot verify the instrument's accuracy during testing sessions conducted in 1997 and 1999)
-witnesses note that the chip inside the gas analysers were replaced midway through the study, making comparisons across this time invalid

For sake of argument, let's accept efficiency data at face value
Has been shown that 60 min of moderate-intensity exercise can reduce GE by 8%
-this coincides almost precisely with the difference between initial and final measures

-pertinent because eyewitness accounts state that Armstrong spent the day riding in Austin mountains with his Dutch Motorola teammate, and if this prior exercise had reduced his efficiency by 8%, then all of the reported differences from this baseline could be due to nothing more than methodological flaws in the data collection.

Validity

-refer to absence of internal validity (gains evident even after reduced training)

-refer to absence of external validity (performances not concordent with improvements reported in efficiency)

Poor study design

-purported to monitor maturation of Armstrong, but failed to even record efficiency parameters at one timepoint

-suggestive of opportunistic data collection rather than controlled study design

-in keeping with my experience testing celebrity athletes, where personal whims and external factors invariably impinge on data collection

More serious is the inclusion of subjective data on Armstrong's weight

-particularly perplexing that a researcher would go to the considerable trouble of doing hydrostatic weighing, and then not even bother to have the athlete report to the lab and have his weight taken at the time of competition

-suggestive that the degree of control over Armstrong's activities enjoyed by Coyle was severely limited

Veracity of the study is brought into question by a photograph of Armstrong being tested on a Schwinn
-contradicts Coyle's statements in both the original manuscript and two subsequent scientific letters responding to concerns raised on this issue
-eight independent investigations have reported differences between the assumed and true power outputs of ergometers that can be as high as 70-80%, demonstrating that it is not tenable to compare power outputs across different ergometers

Dynamic calibration is a pre-requisite for valid data collection
-Maxwell's (1998) study measuring the accuracy of 35 different Monark ergometers not only found that the power output was understimated by 9% (equivalent to the change in power reported by Coyle), but this % error is variable over the power range which precludes any 'across the board' adjustment