The purpose of this study was to examine the relationship between high intensity cycle ergometry when resistive forces were optimised and field tests of high intensity performance in an elite sprint trained group (n=12). Body mass, stature and age of the group were determined prior to testing (66.3±9.8kg, 177±7.6cm and 17±0.74 yrs respectively). Field tests of high intensity performance examined included sprinting, maximal shuttle running and jumping ability (vertical and horizontal). Significant correlations existed between all field tests (P< 0.01). Only moderate correlations were observed for values generated on the cycle ergometer and performance tests (P>0.05). The results of the present study suggest that the optimised cycle ergometer test and the performance tests are unrelated when evaluated statistically. These findings also suggest that the sprinting and jumping tests examined are highly related and may be substituted for each other as possible predictors of high intensity ability.

Introduction
In recent years interest in high intensity energy production has increased. Coaches, trainers and athletes are continually searching for optimum ways of identifying key elements which contribute to athletic performance. Many sporting activities depend upon the development of power for short periods of time. The Wingate 30-s cycle ergometer test and various field tests have been widely employed to assess indices of muscle performance during maximal exercise. Traditionally, the load established for the Wingate test has been set according to body weight, i.e., 75g.kg\(^{-1}\) for a Monark cycle ergometer. More recent studies (Winter,1989) have shown that higher power outputs can be obtained with larger load settings. Dotan and Bar-Or (1983) reported that optimal loads for mean power output per kg body weight were almost identical for male and female subjects, but that higher load settings led to larger peak power outputs. Procedures for measuring high intensity power and capacity have ranged from simple field tests, (jumps and sprints), to laboratory techniques, e.g., treadmill sprinting and cycle ergometry. The aim of the present study was to evaluate the cycle ergometer performance of a group of elite male and female sprinters using the British Association of Sport and Exercise Sciences (B.A.S.E.S.) recommended guidelines for resistive force selection for a single cycle ergometer high intensity test. A further aim was to examine the
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power profiles obtained and to assess their relationship to sprinting and jumping ability in an elite sprint trained group.

Methods
Twelve members of the Welsh International sprint squad volunteered to participate in the study (6 males and 6 females). Ethical procedures were approved by the University of Glamorgan ethical committee. Prior to testing, subjects were familiarised with data collection procedures and the tests themselves on three occasions. During experimental procedures, all subjects were tested at the same relative time interval (morning testing), in the same order and were informed that they were free to withdraw from the experiment at any time. A rest day preceded each test, and subjects attended the laboratory following an 8 hour overnight fast. Body mass, height and body composition was recorded prior to data collection.

Terminology
Throughout the study peak power output (PPO) refers to the highest 1-s value of power attained during each 30-s sprint. Mean power output (MPO) represents the average power output for each 30-s period and end power output (EPO) the value of power in the last second of each sprint. Fatigue index (FI%) refers to the decrease in power from PPO to EPO over test duration, and is expressed as a percentage.

Cycle ergometer test
Subjects were required to pedal maximally on a cycle ergometer (Monark 868, Varberg, Sweden) against a load of 120g.kg\(^{-1}\) for male sprinters and 100g.kg\(^{-1}\) for female sprinters (B.A.S.E.S. 1988) for a period of 30-s. Individual warm up consisted of pedalling for two minutes duration at 20 rpm against a resistance of 0.5kg. This was followed by two consecutive periods of pedalling both lasting 30-s, using two speeds 25 and 45rpm respectively against a resistance of 1.5kg. The ergometer test consisted of sprinting maximally for 30-s duration in a seated position. Saddle heights were adjusted individually, and the feet were firmly supported by toe clips. Subjects were given a 3s count down after which individual loads were applied and data capture initiated. Values for PPO, MPO, EPO and FI% were obtained following test completion using a computer program (Coleman, 1996).

Sprint test
Subjects were required to run between markers placed 30m apart. Individual 30m times were recorded by the same experimenter using a digital stopwatch. Subjects were required to complete three maximal effort sprints in total. The fastest of the three was used as the criterion measure. Reliability for timing was established during a pilot study using a test retest method (r=0.94, P<0.01; t> 0.05).

40m High intensity shuttle run test (HISR)
Subjects were required to run between markers placed 20 m apart. The start point was located at the mid-point of the markers. Before commencement of the test, subjects were given a familiarisation trial of five low intensity runs following test procedures. The 40 m HISR protocol consisted of sprinting from the mid-point to the first marker, turning, running 20 m in the opposite
direction to the second marker, turning and running back again through the mid point, a total distance of 40m. Each sprint was started with a five second count down.

This procedure was repeated on each run with subjects completing three maximal effort sprints in total. A 20s recovery period was allowed between each successive sprint. Individual 40 m and split 10 m times (distance covered from the centre of the course to the first marker) were recorded manually using a digital stopwatch by the same experimenter. Reliability for timing was established using a test re-test method during a pilot study prior to the experiment itself. The fastest 40m and 10m time recorded was used in data analysis.

**Jump tests**

Vertical and horizontal jump tests were performed in a sports hall. The best of three measures was used as the criterion value in both tests. Procedures for test administration and design have been outlined elsewhere (Baumgartner and Jackson, 1991). Established reliability for the jump tests was r=0.92, P<0.01.

**Body fat and body density calculations**

Prior to testing skinfold measurements were taken on the left side of the body at the biceps, triceps, sub-scapular and suprailiac sites using Harpenden callipers. All skinfold thicknesses were taken with the subjects standing in a relaxed position. Three measurements were taken with the average being used as the criterion measure. Body density was determined using the equations of Durnin and Rahaman, (1967), and % fat values using the equation of Siri, (1956)

**Statistical procedures**

Data were analysed using a computerised statistical package (SPSS, Surrey, England). The degree of linear relationship between variables was examined using Pearsons product moment correlation. Conformation that all the dependent variables were normally distributed was assessed via repeated Kolmogorov-Smirnov tests. Significance was accepted at the P< 0.05 level.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Means±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical jump (cms)</td>
<td>52.5 ± 13.3</td>
</tr>
<tr>
<td>Horizontal jump (m)</td>
<td>2.6 ± 0.4</td>
</tr>
<tr>
<td>30M Sprint test (s)</td>
<td>3.3 ± 0.3</td>
</tr>
<tr>
<td>40M Shuttle test (s)</td>
<td>8.6 ± 0.6</td>
</tr>
<tr>
<td>10M Shuttle split (s)</td>
<td>2.2 ± 0.2</td>
</tr>
<tr>
<td>PPO (W)</td>
<td>931± 264</td>
</tr>
<tr>
<td>MPO(W)</td>
<td>644 ± 207</td>
</tr>
<tr>
<td>EPO(W)</td>
<td>426 ± 139</td>
</tr>
<tr>
<td>FI(%)</td>
<td>25.6 ± 12.7</td>
</tr>
</tbody>
</table>

Data are presented as Means±SD

*Table 1: Performance data of subjects (n=12).*
Results

Subject performance values are given in Table 1. Linear relationships are given in Table 2. Significant relationships were found between the 30m sprint test and both jumping tests (vertical jump \( r=0.91, P<0.01; R^2=83\% \), horizontal jump \( r=0.87, P<0.01; R^2=76\% \)). Correlations were also observed between 40m shuttle run times, and both vertical and horizontal jumping ability (\( r=0.81, P<0.01; R^2=66\% \); \( r=0.80, P<0.01; R^2=64\% \) respectively).

Linear relationships were also recorded for the split 10m distances during shuttle running and vertical and horizontal jumping ability (\( r=0.80, P<0.01; R^2=64\% \); \( r=0.80, P<0.01; R^2=64\% \) respectively). Correlation coefficients between the vertical jump and the horizontal jump were \( r=0.86, P<0.01; R^2=74\% \). Relationships were also observed between the running tests, 30m sprint and 10m split shuttle time \( r=0.80, P<0.01; R^2=60\% \), 30m sprint and 40m shuttle time \( r=0.83, P<0.01; R^2=70\% \) and 10m split shuttle time and 40m shuttle \( r=0.90, P<0.01; R^2=80\% \). Only moderate correlations were found between PPO, MPO and EPO values generated on the cycle ergometer and the performance tests (\( r=0.51, P>0.05 R^2=26\% \)). Body fat measurements recorded during the study were in the range of 28.4 to 6.2 with mean values of 15.3 (±7.7\%).

Discussion

Significant correlations were observed between all field measures of high intensity performance (\( P<0.01 \)). There were no relationships observed between high intensity cycle ergometry and the field tests (\( P>0.05 \)). The \( R^2 \) values obtained between the performance tests indicate that the linear relationship accounted for 83% of the variance. The \( R^2 \) values obtained between cycle ergometry and the field tests were only 23% related. These findings are in agreement with Watson et al. (1986) who found poor relationships between PPOs generated during high intensity cycle ergometry and a high intensity skating test (\( P>0.05 \)), and Wragg et al. (2000) who found poor correlations between treadmill sprinting and a repeated sprint test (\( P>0.05 \)). Peak, mean and end power outputs generated during cycle ergometry in this study were higher than those recorded in previous studies (Baker et al., 1993; Beckenholdt et al., 1983; Froese et al., 1987; Tharp et al., 1984) This may be partly explained...
by the optimisation of the resistive load, and other interacting factors such as
contraction velocities, muscle fibre composition and the training status of the
subjects (Froese et al., 1987).

Differences in the relative strengths of correlations suggest that the cycle
ergometer test may be measuring a slightly different component of high
intensity exercise performance than the jump and sprint tests, and corre-
lations obtained between the laboratory and field tests (jumps and sprints)
may be further influenced by test design, suitability and specificity (Baker et
al., 1993). It also appears that the subjects who performed well on the sprint
tests also performed well on the jumping tests. The 10m split times recorded
were only one second faster than the 30m time (2.2±0.2s vs 3.3±0.3s), and the
40m time recorded was five seconds slower than the 30m time (3.3±0.3s vs
8.6±0.2s). The correlations obtained and times recorded between the sprinting
tests may be influenced by shuttle run design which incorporates an
anticipation time for slowing down and turning at both the 10m and 30m
stages during test administration.

During all test protocols, there may be a learning effect, and both poor motor
coordination and individual skill levels in a given performance may contribute
to test results. Care should be taken when selecting an appropriate high
intensity test to ensure that the protocol used is as specific as possible to the
demand and nature of the performance being examined (Beckenholdt et al.,
1983). In addition, each specific test requires a skill component, and skill
specificity dictates that individuals will perform differently on each of the tests.
This problem may be reduced by fully familiarising subjects with test protocols
prior to data collection and is a desirable practice.

The findings of the present study are in agreement with other authors
(Beckenholdt et al., 1983) who suggest that the quantification of high intensity
exercise may be influenced by several factors, including the direction of body
movement during the test, (i.e., vertical or horizontal), muscle contraction
time, type of contraction, recovery duration and test design. These authors
further suggest that the assessment of high intensity performance is more
difficult to quantify than aerobic ability.

Beckenholdt et al. (1983) classified high intensity performance as being
made up of two component parts, one associated with speed, the other with
body mass. While body mass must be manipulated in all tests, the jumps and
sprints appeared to be dominated by a speed phenomenon that was
independent of body mass. This statement can be verified when we consider
that the heaviest subject in this study recorded the fastest times in the
running tests and the greatest distances in the jumping tests. This fact was
supported by the low correlations observed between body weight and the tests
evaluated. Although body mass is an important consideration in any measure
of high intensity exercise performance (possibly to a lesser extent during cycle
ergometry, because body mass is supported), when the values obtained in this
study were expressed relative to body weight (W.kg⁻¹) the strength of the
correlations remained unchanged. These findings suggest that, although body
mass needs consideration, training specificity and the fibre type distribution
within the muscle mass may make a greater contribution to force generation
in activities requiring maximal effort over short periods (Manning et al., 1988).
The results of this study disagree with the findings of other studies (Bar-Or
et al., 1978; Rhodes et al., 1985; Baker et al., 1993) who showed that power outputs generated during 30s of high intensity cycle ergometry, were correlated with sprinting ability (P<0.05). This finding may be explained by the fact that the subjects examined during the present investigation were high level international sprinters, and may have been more powerful, with greater running efficiency than the subjects used in previous studies.

The relative strengths of the correlations may have been influenced by the optimal resistive forces used for the cycle ergometer test in this study. Dotan et al. (1983) reported that high power outputs during cycle ergometry were due to optimisation of the resistive load. Previous studies have employed resistive forces based on 75g.kg⁻¹. The resistive forces used in this study were much larger (120g.kg⁻¹ for male sprinters and 100g.kg⁻¹ for female sprinters; B.A.S.E.S. 1988). The increases in resistive force used may have produced greater optimal power profiles for cycle ergometry than those produced in previous studies. These profiles may be less related to running and jumping ability than the lighter resistive forces used previously. During the running and jumping tests, the resistance force may not be optimal and body weight is not supported.

This suggestion is supported by the work of Caiozzo et al. (1980) who found significant increases (P< 0.05) in power outputs when subjects were externally loaded during a stair running test. The linear relationships recorded between the field tests suggest that the sprint, maximal shuttle test, vertical and horizontal jump test can be used interchangeably, and that the cycle ergometer test, although maximal in execution, is not related to field measures. In addition, the linear relationships observed between the field tests and the high intensity cycle ergometer test may be influenced by the role of the upper body in the measurement of leg power (Baker et al., 2001) and resistive force selection based on body mass indices (Baker et al., 2001). However, further research is required to confirm this, and caution must be exercised in the interpretation of results that relate to athletic performance.

**Conclusion**

It appears from the findings of this study that high intensity sporting ability may be better evaluated using a battery of sport specific field tests. The strengths of the correlations observed between the jump and sprint test suggest that both may be used to predict jumping or sprinting ability, which would be beneficial to most team sports that utilise this type of activity. The direction of the jump test used to predict sprint performance could be decided on the specificity of the movement inherent in the performance being evaluated. The coefficient of determination values suggest that the cycle ergometer test may be measuring a different component of high intensity ability to that of the field tests, and the values obtained do not relate well to sprint/jump performance. The results of this study also indicate that field tests specific to a sport may be more applicable in the evaluation of high intensity ability related to that sport.

**References**

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