Forced Vital Capacity and aerobic power

Introduction:
Aerobic power is defined as the “highest amount of oxygen a person can consume during maximal exercise of several minutes’ duration. It is demonstrated by a levelling off, or decline, in oxygen consumption with increasing intensity”\(^1\). Measurement of aerobic power enables a coach or medical practitioner to find a person’s aerobic capacity. The best measure of this component of fitness is via maximal tests\(^2\) such as the gold standard test, which “refers to a diagnostic test or benchmark that is the best available test under reasonable conditions”\(^3\). VO\(_{2}\)\(_{max}\) measured using a treadmill and machinery to analyse the oxygen used by a subject, to measure the maximum volume of oxygen that an individual can utilize during intense or maximal exercise\(^4\); is an example of an appropriate maximal test (gold standard). These tests do however involve subjects working to a maximum level, which can be extremely stressful and time consuming.

I am going to investigate whether there is a correlation between aerobic power (ml/kg/min), as estimated by the Beep Test, and the Forced Vital Capacity (cm\(^3\) ±25 cm\(^3\)), in 15 males aged between 15-17 from my school High Performance Football Squad.

I selected this topic initially as it directly links to my activities of football, running and hockey. That is, that our aerobic fitness is often measured using maximal testing situations. But after some foundation research I realised its use could be far broader and more effective. A study by the University of Western Australia\(^5\), investigated the use of sub-maximal tests for those physically unable to do maximal tests. A sub-maximal test would have an athlete working below 100% during the test and this can be used to estimate maximal VO\(_2\). Further research by Mohammadi et al (2014)\(^6\) showed that for subjects with asthma there was a positive correlation (r=0.42) between VO\(_2\)\(_{max}\) and Forced Vital Capacity. This inspired me to see if there is a similar correlation between Forced Vital Capacity (FVC) and Aerobic Power in subjects who are active in a high performance sports team, and to see how strong this relationship is. This could assist sports coaches and physical education teachers to measure and monitor athletes and student’s aerobic capacity with a great deal of ease and less stress, and may mean that students such as myself don’t need to undergo the maximal tests in order to get an accurate VO\(_2\)\(_{max}\) score.

The research into the correlation between VO\(_2\)\(_{max}\) and FVC has varied; some studies have shown improvements in FVC from performing hyperventilation however, there was no improvement in VO\(_2\)\(_{max}\).\(^7\) In a study of the change of cardiorespiratory fitness by comparing vital capacity (VC) and endurance running performance of Chinese students from 1985 to 2010 it was found that both dependent variables decreased during this time. The research mentioned above from Mohammadi et al (2014) indicates that there is at least a positive relationship – be it small. VO\(_2\)\(_{max}\) is a tangible measure of a person’s aerobic power, as it measures the oxygen uptake of their body, whilst performing an aerobic exercise maximally. For this experiment cardio-vascular fitness will be measured using the Beep test, as access to a treadmill and oxygen measuring devices is not available. Additionally the Beep test is a known valid

\(^1\) http://medical-dictionary.thefreedictionary.com/aerobic+power
\(^2\) http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3763116/
\(^3\) http://en.wikipedia.org/wiki/Gold_standard_%28test%29
\(^4\) http://www.medicine.virginia.edu/research/cores/exercise-physiology/fitness-assessment/vo2-maximal-oxygen-consumption.html/
\(^5\) http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3763116/
\(^6\) http://www.jsams.org/article/S1440-2440%2812%2900759-1/abstract
\(^7\) http://www.jsams.org/article/S1440-2440%2812%2900346-5/pdf
\(^8\) http://www.jsams.org/article/S1440-2440%2812%2900346-5/pdf
indicator of a person’s VO\textsubscript{2max} (r=0.92), and so will be a very good test to use in this case, and I will be able to test a large group at once with this test.

**Aim:**
The aim of the following study is to investigate the correlation between the aerobic fitness scores obtained from the 20 m shuttle run test (the Beep test) and forced vital capacity obtained from a spirometer in 15 of 15-17 year old male subjects.

**Independent Variable:**
15 teenage males aged between 15-17, from my school high performance football squad

**Dependent Variables:**
- **Aerobic power:** Measure using the Beep test (Level and shuttles completed) and converted into ml/kg/min (±1 ml/kg/min) and Vital Capacity: measured using a spirometer cm\(^3\) (±25cm\(^3\))

**Controlled Variables:**
- **Sample, Skill and fitness Level:**
  15 Players from my schools Football High Performance Squad, which is also known as the Premier team. By testing after a 6 week fitness program, the players should be of a similar fitness as well as have similar agility fitness based on their backgrounds from football. This way the results won’t be affected by a wide range of skill and fitness levels.
- **Type of Test:**
  - Aerobic power measured using the ‘beep’ test (VO\textsubscript{2max}) which is also known as the Multi Stage Fitness Test and Spirometer (Forced vital capacity).
- **Trials & Repeats:**
  - Vital Capacity will be measured through the use of the spirometer and each participant tested 3 times. The beep test will be performed twice on different days.
- **Practice:**
  - 1 practice attempt will be given for the spirometer as it is a new piece of equipment which requires a technique to try and ensure results are reliable. Due to the ‘beep’ test being a maximal test a practise attempt would not result in reliable data as participants would not be able to put the same amount of effort in a 2nd time. This maintains accuracy, and therefore validity.
- **Environment/location:**
  - Controlled by using the same setting – 1st XI Hockey Turf and in turn reduce effect of different weather or surface for subjects.
- **Age and Gender:**
  - Limited to males aged 15-17 (squad members) from Football High Performance Squad members to try and minimise the effect of skill and fitness level being tested.
- **Rest Period:**
  - By testing the subject’s Vital Capacity before the Beep test, the amount of immediate rest isn’t an influencing factor. Students will be asked if they have exercised within 24 hours of the test, if they have they will be omitted from the study.
- **Time of Day:**
  - Conducted between 8.00 – 9.00am to try and minimize effect of the climate (18\(\degree\)C) on subjects’ performance, in addition to students being ‘fresh’ from a good nights sleep.
- **Instant preparation:**
  - By getting them to do the same warm up, all subjects will be similarly prepared, so their results will be a reflection of their maximum performance.
- **Randomization:**
  - Students will be called in alphabetical order to under go the Vital Capacity using the spirometer with the same order being kept throughout the testing process. The aim is to try and remove influencing variables on results e.g. Two good players and friends are after each other, so become competitive.
- **Instructions:**
  - Instructions will be given verbally at the same time by the same conductor (me) to ensure all participants are presented with the same instructions. This should in turn, help to minimise wrong interpretation by subjects and have same circumstances for each subject.
- **Warm-up:**
  - 10 Minute warm up will be carried out to raise heart rate levels and reduce injury and led by test conductor to ensure participants are ready for high intensity levels on the beep test. Aim is to simulate conditions prior to a competitive game as rarely will a player play without undergoing a cardiovascular warm up followed by dynamic stretching.
- **Equipment:**
  - Equipment and environmental conditions will be the same for all participants (see equipment list below)
Prior Nutrition
Request subjects have quality fuel and fluid beforehand in order for their bodies to digest the food and have appropriate energy for the experiment so it doesn’t inhibit their performance.
- Breakfast (porridge) around 2 hours before the start time (8am)
- Nutritional energy snack food within 20 minutes of warm-up e.g. Milo bar

Hydration
Request subjects bring at least a litre of water to the test, and consume at least 1 litre within 2 hours before the start. This way their bodies will be at a good hydration level, and therefore won’t have an effect on their performance.

Kit worn: (Trainers, Socks, Football Shorts, Sports Shirt)
Chosen by subject so they are comfortable and in gear that realistic to football setting, all subjects were informed they must wear trainers to ensure friction was not a factor on turning in the beep test.

Compounding Variables:
- Prior fatigue, fitness and preparation - Physical activity done at least a day before
- Illness prior – Use of PAR-Q (see appendix) will detect any physical conditions such as lung infection, cough etc which may affect their performance.
- Weather – Weather characteristics will be recorded as they could affect the subject’s performance with grip and air resistance. Also, the mental state of the subjects can be affected if they are cold and miserable.
- Mental state of subjects - desire to reach 100% max: If they aren’t motivated or in anyway not fully applied to the task, then their performance won’t be reliable. The subjects will be spoken to regarding their involvement and that if they proceed with being involved with the investigation that a full 100% effort is required for the results to be valid.

Safety and ethical considerations:
- For ethical purposes I will gave the squad members a parental permission a day before, to bring on the day. This will be included in the custom PAR-Q form (see below), which will be used for qualitative data as well as seeing if a subject is unable to the activity due to health reasons. Students informed that all results will be confidential and anonymous and they can withdraw at any time.
- If students are injured through the test, they will be allowed to stop immediately and medical assistance if required will be sought.
- Saliva from mouthpieces is a potential ‘health’ issue and all will be labelled and placed in separate spaces to avoid cross contamination. Hygiene will also be addressed through the experimenter wearing rubber gloves to prevent skin contact and further contamination.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Quantity</th>
<th>Size</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beep test CD</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Portable Speaker – CD player included</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Recording device (clipboard)</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mouth pieces</td>
<td>15+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spirometer with instructions and 50 mouth pieces</td>
<td>1</td>
<td>-</td>
<td>±0.25 cm³</td>
</tr>
<tr>
<td>Wipes</td>
<td>15+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pen/Pencil</td>
<td>10+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PAR-Q forms</td>
<td>15</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cones</td>
<td>20</td>
<td>Ground Disks</td>
<td>-</td>
</tr>
<tr>
<td>Tape Measure</td>
<td>1</td>
<td>30 m</td>
<td>±0.01 m</td>
</tr>
<tr>
<td>Extension Cord</td>
<td>1</td>
<td>15 m+</td>
<td>-</td>
</tr>
<tr>
<td>Rubber gloves</td>
<td>Multiple pairs</td>
<td>large</td>
<td>-</td>
</tr>
</tbody>
</table>
**METHOD**

**Stage 1: Introduction (During a training session the day before)**
1. Distribute 15 permission slips (PAR-Q), and ask for declarations of related medical issues that could influence results. Inform subjects that at any stage they are able to leave the experiment and results will be confidential.
2. Request that subjects follow nutritional, hydration and kit advice (see controlled variables).
3. Give them details of testing location (1st XI Hockey Turf) and protocol (XXXX).
4. Have a staged run through of the set-up, especially Beep Test and spirometer, to ensure equipment works.
5. Convert names of subjects to numbers so student are organised alphabetically with the same order being followed throughout the test.

**Stage 2: Preparation**
1. Throughout the test, make observations that may affect the results and list them, such as
   - Weather (using metservice.co.nz (humidity, temperature, wind speed)
   - Condition under foot (wet, damp, moist or dry)
   - Other variables that could affect physical or mental state of subjects E.g. Stormy night prior
2. Collect in PAR-Q sheets – checking if any boxes have indicated inability to do testing, if so, students are asked to not take part in the tests.

**Stage 3: Forced Vital capacity**
1. Have labelled mouthpieces for each subject.
2. Put gloves on when handling these.
3. Set the spirometer to zero.
4. Have subjects inhale maximally.
5. Then place the mouthpiece into their mouths and breath out **strongly** in one continuous breath.
6. Record the reading of lung capacity.
7. Repeat Steps 2-3 until the subject has been tested 3 times.
8. Change the mouth piece and dry the machine before the next subject.
9. Repeat steps 2-7 for each subject.

**Stage 4: Beep Test**
1. Set up beep test – CD and speaker and check it works.
2. Explain to the 15 participants what’s being tested, and how it will be done.
3. Lead the subjects on 10 minute warm up that increases in speed and has **dynamic stretching**.
4. Confirm all participants are willing and able to proceed with the test before letting them have final drink/prep
5. Line all subjects along the start line and play the CD instructions for test.
6. Pause CD and check everyone understands.
7. Play the CD.
8. Encourage people to try and reach their physical maximum during the test.
9. Record peoples’ results as they reach their max (finish/pull out) by noting their **level** and how many **shuttles** they ran. An error of ±1 shuttle has been used in order to account for the possible error made by the experimenter when listening and recording multiple subjects doing the test at any one time.
10. Continue recording until the last one has finished.
11. Ensure the subjects hydrate, refuel and cool down correctly.
12. Repeat steps 1 to 11 one more time on the next day.

---

EX 3 & EX 4: Appropriate method which is easy to follow and covers relevant aspects.

EX 3 & EX 4: FVC not referenced.

EX 3: Lack of detail.

EX 3: Lacking in detail.

EX 3: No inclusion to show the type of dynamic stretching undertaken or cardiovascualr activity.

EX 3: CD not referenced.

EX 3: Not clear as to when students may be asked to stop the test if they do not reach the line twice. Major flaw in the design.
Results

Observations/ qualitative data

Environment
During the tests, the climatic factors remained relatively even with the temperature sitting around 18°C and the wind around 20 km/hr. However, due to the sheltered location, this wasn’t a major issue. The air itself was around 60% humidity for each test, reflecting the similar circumstances for the tests.

Vital Capacity
- The instructions given were very similar each time, with all subject understanding what was needed after one practice attempt.
- Techniques varied, with some not blowing at consistent rate, this not giving a fair reflection on their true Vital Capacity. Subjects varied their mouth position of the mouth piece, which may have affected the flow going into the equipment.
- As people were queuing, a subtle competition occurred, which prompted subjects mentally to be serious and try their best, aiding their results.
- I was very meticulous in getting the line back to zero each time and accurately reading the scale, which reduced the room for error.

Beep test
- Warm-up was thorough and done by everyone properly. I took a strict and firm approach to ensure everyone followed the steps.
- Technique was evident throughout, with those having clear experience hitting the line and turning on the beep, instead of running to the line and waiting (subject 9 and 13).
- Cool down was thorough again, and done by all.
- Water was accessible next to the turf with two fountains. All subjects brought bottles. Most seemed to be drinking before with everyone drinking after.
- The subjects lined up next to their friends, which proved to be an incentive during the test as they wanted to keep up with one another. However, when one of them dropped out (subject 2), his friend did too (subject 3). There were a couple of examples of this, but towards the end, the final few competitors looked to beat one another, evidently pushing themselves, with the final 3 on the floor at the end.
- Mental state overall appeared tired and sleepy, which was understandable as it was early morning towards the end of the school year. I feel for most subjects, this wore off as endorphins, adrenaline and competition kicked in during the Beep Test. However, this could have affected the Forced Vital Capacity measurements slightly.
- Coaches and manager helped out by shouting encouragement and ensuring those who didn’t hit the line, got the 1 warning as was in the instructions. They also indicated to the subjects not to go early. This was a considerable help, as keeping track of 15 people created a far higher chance of error. Their help reduced the room for error as well as ensuring technique – reaching the line.
- Due to the first subjects waiting around for over 10 minutes after their Vital Capacity, I proceeded with the warm-up before the instructions. While I did state and play the CD instructions during static stretches of their choice, this would have affected the effect of the warm-up on their performance. However, the length of time shouldn’t have had a major effect.
- To ensure a proper test, I started the test from level 1, which meant walking at the start. While time consuming, it did give a chance for subjects to adjust to the style and pace of the test, promoting technique and therefore better performance.
- Downwind on return leg may have had an impact; however it was hard to register on the skin unless you were consciously looking for it. It would have had more an impact going upwind, as there was more resistance to the subjects forward motion. This was the same for all subjects, however.
- Interestingly those who finished earlier appeared to recover quickly within the first 3 minutes of finishing, with a few laughing amongst each other. In comparison, those at the end were on the floor panting for air, suggesting the early people could have worked harder and gotten a better result. Indicating perseverance was a large influence on the result.
Table 1: Beep Test

<table>
<thead>
<tr>
<th>Subject</th>
<th>Year (±1 shuttle)</th>
<th>Beep Test Score 1 (level ±1 shuttle)</th>
<th>Beep Test Score 2 (level ±1 shuttle)</th>
<th>Highest Beep Test Score (level ±1 shuttle)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>11.07</td>
<td>12.06</td>
<td>12.06</td>
<td>Worked hard, had some breakfast</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>10.02</td>
<td>10.04</td>
<td>10.04</td>
<td>Had some breakfast</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>9.07</td>
<td>10.04</td>
<td>10.04</td>
<td>Had some breakfast</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>9.01</td>
<td>10.03</td>
<td>10.03</td>
<td>Knee ligament issues</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>10.01</td>
<td>11.00</td>
<td>11.00</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>12.00</td>
<td>12.01</td>
<td>12.01</td>
<td>Had some breakfast</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>8.09</td>
<td>9.05</td>
<td>9.05</td>
<td>Had some breakfast</td>
</tr>
<tr>
<td>8</td>
<td>11</td>
<td>8.03</td>
<td>9.04</td>
<td>9.04</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>13</td>
<td>11.00</td>
<td>12.00</td>
<td>12.00</td>
<td>Had some breakfast</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>8.02</td>
<td>9.00</td>
<td>9.00</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>10.03</td>
<td>10.10</td>
<td>10.10</td>
<td>Had some breakfast</td>
</tr>
<tr>
<td>13</td>
<td>11</td>
<td>9.00</td>
<td>9.03</td>
<td>9.03</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>7.01</td>
<td>8.02</td>
<td>8.02</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>12</td>
<td>9.07</td>
<td>10.06</td>
<td>10.06</td>
<td></td>
</tr>
</tbody>
</table>

Note: Beep test score were measured in level and shuttle number; so a subject who got level 1 shuttle 1 would read as 1.01.

Table 2: Spirometer

<table>
<thead>
<tr>
<th>Subject</th>
<th>Year Group</th>
<th>Vital Capacity (cm³ ±25 cm³)</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Highest</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>3850</td>
<td>3825</td>
<td>3925</td>
<td>4325</td>
<td>4325</td>
<td>Good technique</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>3725</td>
<td>4305</td>
<td>4350</td>
<td>4450</td>
<td>4450</td>
<td>Good technique</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>3600</td>
<td>4175</td>
<td>4400</td>
<td>4400</td>
<td>4400</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>3175</td>
<td>3650</td>
<td>3650</td>
<td>3650</td>
<td>3650</td>
<td>Technique improved</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>4450</td>
<td>4525</td>
<td>4715</td>
<td>4715</td>
<td>4715</td>
<td>Poor technique</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>3525</td>
<td>4750</td>
<td>4650</td>
<td>4635</td>
<td>4675</td>
<td>Good form in trial two</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>3200</td>
<td>3225</td>
<td>3325</td>
<td>3325</td>
<td>3450</td>
<td>Short and small</td>
</tr>
<tr>
<td>8</td>
<td>11</td>
<td>3250</td>
<td>2175</td>
<td>2350</td>
<td>2650</td>
<td>2650</td>
<td>Weak flow</td>
</tr>
<tr>
<td>9</td>
<td>13</td>
<td>3250</td>
<td>5200</td>
<td>5000</td>
<td>5325</td>
<td>5325</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>4388</td>
<td>4200</td>
<td>3925</td>
<td>3450</td>
<td>3300</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>13</td>
<td>3700</td>
<td>3875</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>3900</td>
<td>3925</td>
<td>3900</td>
<td>3925</td>
<td>3925</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>11</td>
<td>6000</td>
<td>5800</td>
<td>5800</td>
<td>6000</td>
<td>6000</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>3125</td>
<td>3225</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
<td>Tall for age</td>
</tr>
<tr>
<td>15</td>
<td>12</td>
<td>5800</td>
<td>5250</td>
<td>5050</td>
<td>5350</td>
<td>5350</td>
<td>Consistent and focused</td>
</tr>
</tbody>
</table>

A1 and A3: Quantitative data effectively processed. Error margins are indicated in the table. The uncertainty in the table doesn't appear to match the precision of the data in the table but the statement beneath which explains the annotation used seems to cover this.

A 3: Error of measurement used in raw data.
Table 3:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Beep test score (level.shuttle±0.01)</th>
<th>VO_{\text{max}} (ml/kg/min ±0.3 ml/kg/min)</th>
<th>Highest Forced Vital Capacity value (cm$^3$±25 cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.06</td>
<td>68.9</td>
<td>4325</td>
</tr>
<tr>
<td>2</td>
<td>10.04</td>
<td>59.4</td>
<td>4450</td>
</tr>
<tr>
<td>3</td>
<td>10.04</td>
<td>59.4</td>
<td>4400</td>
</tr>
<tr>
<td>4</td>
<td>10.03</td>
<td>59.0</td>
<td>3650</td>
</tr>
<tr>
<td>5</td>
<td>11.00</td>
<td>62.0</td>
<td>4725</td>
</tr>
<tr>
<td>6</td>
<td>12.01</td>
<td>67.0</td>
<td>6475</td>
</tr>
<tr>
<td>7</td>
<td>9.05</td>
<td>55.6</td>
<td>3450</td>
</tr>
<tr>
<td>8</td>
<td>9.04</td>
<td>55.2</td>
<td>2650</td>
</tr>
<tr>
<td>9</td>
<td>12.00</td>
<td>66.6</td>
<td>5325</td>
</tr>
<tr>
<td>10</td>
<td>9.00</td>
<td>53.7</td>
<td>4350</td>
</tr>
<tr>
<td>11</td>
<td>10.01</td>
<td>58.2</td>
<td>4000</td>
</tr>
<tr>
<td>12</td>
<td>9.03</td>
<td>54.8</td>
<td>3925</td>
</tr>
<tr>
<td>13</td>
<td>11.01</td>
<td>62.4</td>
<td>6000</td>
</tr>
<tr>
<td>14</td>
<td>8.02</td>
<td>50.3</td>
<td>3300</td>
</tr>
<tr>
<td>15</td>
<td>10.06</td>
<td>60.1</td>
<td>5350</td>
</tr>
</tbody>
</table>

Correlation VO_{\text{max}} to Highest Vital Capacity value $0.59$

This figure shows there is a strong positive correlation between the subjects VO_{\text{max}} and their vital capacity.

The highlighted subjects are deemed to be further from the line of best fit than other subjects. Subject 1 and 8 both had a very high VO_{\text{max}} in relation to the FVC.

Note:
- Beep test score were measured in level and shuttle number; so a subject who got level 1 shuttle 1 would read as 1.01.
- VO_{\text{max}} scores were converted using the website: [http://www.topendsports.com/testing/Beepcalc.htm](http://www.topendsports.com/testing/Beepcalc.htm) where the shuttle and level score were put into the calculator provided and the corresponding VO_{\text{max}} was provided. The error for VO_{\text{max}} (±0.3 ml/kg/min) the error provided by the website for the calculation tool.

---

Elite Male Athletes

The following equation, to calculate VO_{\text{max}} using the MSPT, was determined by Kriog et al. (2006)\textsuperscript{[1]} in their research with 26 elite, male, intermittent sport athletes.

\[
\text{VO}_{\text{max}} (\text{ml/kg/min}) = 0.36 \times \text{total number of shuttles completed} + 25.98
\]

---

\footnote{http://faculty.quinnipiac.edu/libarts/polsci/statistics.html}

**A 2:** Data in tables is processed accurately. This is effectively using the data to enable a conclusion to be drawn.

**A 2:** Beep test to VO_{\text{max}} conversion reference.

**A 3:** Uncertainty considered.
The correlation was calculated using Microsoft Excel as shown below:

- The correlation coefficient was calculated using Microsoft Excel as shown below.
- The correlation coefficient was calculated using Microsoft Excel as shown below.

### Table showing Highest Beep Test scores for each subject and their Highest Vital Capacity value (VCC)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Beep Test Score</th>
<th>VO₂max (ml/kg/min)</th>
<th>Highest Vital Capacity (VCC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.04</td>
<td>46.2</td>
<td>6520</td>
</tr>
<tr>
<td>2</td>
<td>22.04</td>
<td>49.6</td>
<td>6420</td>
</tr>
<tr>
<td>3</td>
<td>21.03</td>
<td>40.3</td>
<td>6380</td>
</tr>
<tr>
<td>4</td>
<td>19.03</td>
<td>39.3</td>
<td>6250</td>
</tr>
<tr>
<td>5</td>
<td>18.03</td>
<td>38.3</td>
<td>6110</td>
</tr>
<tr>
<td>6</td>
<td>17.02</td>
<td>37.3</td>
<td>6070</td>
</tr>
<tr>
<td>7</td>
<td>16.01</td>
<td>36.2</td>
<td>6000</td>
</tr>
<tr>
<td>8</td>
<td>15.00</td>
<td>35.4</td>
<td>6030</td>
</tr>
<tr>
<td>9</td>
<td>14.00</td>
<td>34.5</td>
<td>6090</td>
</tr>
<tr>
<td>10</td>
<td>13.00</td>
<td>33.5</td>
<td>6120</td>
</tr>
<tr>
<td>11</td>
<td>12.00</td>
<td>32.3</td>
<td>6150</td>
</tr>
<tr>
<td>12</td>
<td>11.00</td>
<td>32.2</td>
<td>6080</td>
</tr>
<tr>
<td>13</td>
<td>10.00</td>
<td>31.2</td>
<td>6060</td>
</tr>
<tr>
<td>14</td>
<td>9.00</td>
<td>30.5</td>
<td>6000</td>
</tr>
<tr>
<td>15</td>
<td>8.00</td>
<td>29.7</td>
<td>5920</td>
</tr>
</tbody>
</table>

### Graph showing the correlation between VO₂max and Vital Capacity

\[ y = 135.23x - 3622 \]

\[ R^2 = 0.4753 \]
The $R^2$ figure of 0.4753 indicates the error indicated by the data. This equates to an $r$ of 0.69, which is considered to be a strong positive correlation as mentioned earlier.
Conclusion:

The findings of this investigation shows that a very strong correlation exists between Forced Vital Capacity (FVC) and VO2max in teenage males (from my school’s football High Performance Squad). This is shown by the line of best fit from graph 1 together with a correlation coefficient of r=0.71 (R^2=0.50). This correlation indicates that for this particular group of subjects ‘there is a strong positive correlation’. This means that as FVC goes up there is a corresponding increase in the subjects VO2max, which strongly indicates a positive relationship between FVC and VO2max. This result is obtained through the use of the following steps:

1. Obtaining sound data from the subjects was greatly helped by repeating the tests for each measurement (beep test performed twice; FVC performed 3 times). The data in table 1 indicates that every subject improved on their beep test the second time through. This was possibly due to understanding the test a little better and knowing their limits. However, the same did not occur for the FVC measure as can be seen in table 2. The best scores were from any one of the 3 tests completed. The variation of the FVC is also interesting to note, especially for subject 6 who clearly had a poor initial attempt. It is also worth noting subject 1 and 8’s data in table 2 (highlighted). Their FVC and VO2max scores are amongst the furthest from the regression line and if they are removed from the data the correlation jumps to a figure greater than 0.8. Overall this indicates the need for multiple attempts (possibly more than what I have done) in order to gather accurate data and this will be discussed further on in the evaluation.

2. Additional observations, which were made, also help explain the trend I have found which while it is considered “very strong” still has room for improvement. Whilst instructions, warm-ups and the physical environment were nearly identical each time, the subject’s performance still differed. When testing the Vital Capacity I explained to the subjects how the equipment worked, while pointing at the relevant aspects of the equipment. Even with a practice attempt, the subject’s mouth positions varied during the trials, affecting the equipment readings for each person. It was noticed those with a higher FVC generally had better technique. Additionally, I observed a competitive atmosphere developing during the course of the FVC testing, as the subjects waiting could see each other’s performance. This prompted the latter subjects to seemingly try harder, using the previous subject’s results as a motivator. This is most evident with subject 6’s result of 6475 cm^3, who was the final subject to be tested. The beep test performance itself was even more technique based, with those having previous experience generally going further than those who didn’t. This was seen with some subjects (subject 9 and 13) hitting the line as the ‘beep’ sounded, rather than those who got there at varying times. Familiarisation with the test may have allowed them to pace themselves, giving them more energy in the quicker levels. By knowing the time-period of the test, the subjects were able to control their pace, as opposed to those who were rushing to the line before the beeps. By sticking with the rhythm of the test it would have delayed the build of lactic acid by their bodies (comparatively), potentially allowing them to run further into the test and gain better results.

Evaluation:

There were a number of methodological aspects that caused issues with the quality of my experiment. These will be discussed below.

For the FVC test, the subjects were given the same scripted instructions and allowed 1 practice attempt. This proved to be insufficient, based on the range of techniques observed. "Techniques varied... some not blowing at consistent http://faculty.quinnipiac.edu/libarts/polisci/statistics.html
rate...not giving a fair reflection on their true Vital Capacity). To remedy this subject's needed to have more practice (at least 3 times) in order to allow them to master the technique and generate a consistent result. This would mean that they would get 6 attempts at this test.

Another aspect, which became an issue that affected the results (Beep Test and FVC), was the social-competitive atmosphere. While it gave incentive for the subjects, only some benefited, with subjects dropping out in the Beep Test soon after their friend. This meant that some subjects true VO2max level was not attained, and potentially affecting the correlation. This was also seen in the FVC testing, where those at the rear of the queue tried to beat their peer's previous results. This ability to know each others results disadvantaged those who went first, as they didn't have the same social incentive to aim for. By isolating the testing in a separate room on their own, especially for Vital Capacity, more accurate data could be achieved next time. It is however, worth noting that this could reduce the competitive edge and students may not try as hard. For the Beep test, the impact of testing individually would create issues such as maintaining the same environment, which would have a bigger impact than running the test for all subjects at once. Again it may reduce the competitive edge and mean students do not push them selves as hard. A solution could be to allow for a greater number of repeats of the Beep Test and to incorporate a practice run through for all subjects (4 times with 1 being a practice) to get used to the technique and gain an understanding of their limits. This would also eliminate the impact that was seen by those who had previous experience with the beep test.

The numerical measurement errors were ±25 cm³ for Vital Capacity as the dial went up in 50 cm³ increments. The beep test error was ±1 shuttle, which would have influenced the VO2max result by around ±0.3 ml/kg/min. The volume error is small when compared to the variation seen by subjects and so is acceptable. The beep test error is also at an acceptable level and when translated into ml/kg/min comes out at a very small and acceptable figure.

The sample size (football squad) was too small as only 15 players were used. By having a larger sample (50+ subjects), the validity of this investigation could have been strengthened. Additionally having a sample drawn from different populations this relationship would be able to be tested to see if it has a broader application.

**Strengths**

Controlling the skill and fitness level of the subjects was relatively straightforward as the sample came from the premier football squad. The thought behind this was that they would have similar fitness levels (although the skill level for the actual testing did vary) as shown by the Beep Test and Vital Capacity observations and as previously mentioned.

The temperature, humidity and weather were similar on both testing days (approximately 18°C|20 km/hr|60% RH), which was fortunate as these are nearly impossible to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.

Using the same equipment and instructions maintained the measurement error and their effect on the results. Controlling the kit worn was simple as the sample group was familiar with the kit requirements for the type activity because of their football background. However, managing nutrition and hydration were the hardest to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.

Using the same equipment and instructions maintained the measurement error and their effect on the results. Controlling the kit worn was simple as the sample group was familiar with the kit requirements for the type activity because of their football background. However, managing nutrition and hydration were the hardest to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.

Using the same equipment and instructions maintained the measurement error and their effect on the results. Controlling the kit worn was simple as the sample group was familiar with the kit requirements for the type activity because of their football background. However, managing nutrition and hydration were the hardest to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.

Using the same equipment and instructions maintained the measurement error and their effect on the results. Controlling the kit worn was simple as the sample group was familiar with the kit requirements for the type activity because of their football background. However, managing nutrition and hydration were the hardest to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.

Using the same equipment and instructions maintained the measurement error and their effect on the results. Controlling the kit worn was simple as the sample group was familiar with the kit requirements for the type activity because of their football background. However, managing nutrition and hydration were the hardest to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.

Using the same equipment and instructions maintained the measurement error and their effect on the results. Controlling the kit worn was simple as the sample group was familiar with the kit requirements for the type activity because of their football background. However, managing nutrition and hydration were the hardest to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.

Using the same equipment and instructions maintained the measurement error and their effect on the results. Controlling the kit worn was simple as the sample group was familiar with the kit requirements for the type activity because of their football background. However, managing nutrition and hydration were the hardest to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.

Using the same equipment and instructions maintained the measurement error and their effect on the results. Controlling the kit worn was simple as the sample group was familiar with the kit requirements for the type activity because of their football background. However, managing nutrition and hydration were the hardest to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.

Using the same equipment and instructions maintained the measurement error and their effect on the results. Controlling the kit worn was simple as the sample group was familiar with the kit requirements for the type activity because of their football background. However, managing nutrition and hydration were the hardest to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.

Using the same equipment and instructions maintained the measurement error and their effect on the results. Controlling the kit worn was simple as the sample group was familiar with the kit requirements for the type activity because of their football background. However, managing nutrition and hydration were the hardest to control, although having the tests at the same time significantly helped. Keeping a consistent location for the testing was effective as the hockey turf is always available at 6.45-7.45am. However, if weather was poor, a suggested improvement could be moving the beep test to an indoor facility such as a gym, allowing more control of temperature, wind and humidity.

By warming up with all the subjects for the beep test, their rest period was identical (1 minute before test), enhancing the validity of the results. This caused their instant preparation to be identical also. Randomising the subjects for the Vital Capacity was easy to control, through using an alphabetical list. This prevented any friends going after each other.
An alternative method to achieve the investigation's aim could be carried out. Changing the beep test to using a treadmill and the relevant machinery to analyse the oxygen used by a subject would provide direct measures of VO2max and would possibly push the subjects further as they would be performing it individually. While expensive and time-consuming, the data would prove very accurate and reliable, as the conditions would be very similar and measured with reliable equipment. In future studies it would be preferable to keep the groups as similar as possible so that specific group's data could be looked at to see whether the correlation is strong; this then could enable the use of the FVC to be investigated for different groups, as discussed in the introduction of this study.

Appendix 1

PAR-Q COPY

I am investigating the relationship between a person's aerobic power and their forced Vital Capacity (FVC) as part of my IA for BTEB. In order to gather data I am inviting you to take part. The testing will involve subjects completing a 20m shuttle run test and also performing a Forced Vital Capacity using a spirometer. The following questionnaire is designed to:

- Obtain permission for you to take part in the investigation
- And to check whether there is any physical/health reason why you should not be involved. Please read the following questions carefully and answer YES or NO.

Question | YES/NO
--- | ---
(1) Have you ever had chest problems? | YES/NO
(2) Do you frequently have pain in your chest? | YES/NO
(3) Do you often feel faint or have spells of dizziness? | YES/NO
(4) Have you ever had your blood pressure too high? | YES/NO
(5) Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise or that might be made worse by exercise? | YES/NO
(6) Is there a good medical reason not mentioned here why you should not follow an activity program even if you wanted to? | YES/NO
(7) Have you participated in any exercise in the last 24 hours? | YES/NO
(8) Are you taking medication that might affect your response to exercise? | YES/NO
(9) Have you been prescribed or are you taking drugs that reduce your blood pressure or reduce your heart rate? | YES/NO

If you have answered YES to one question or more then you should consult with your doctor BEFORE taking part in this investigation. If you have answered NO to all questions and you have answered accurately, you have reasonable assurance of your present suitability to participate safely.

Declaration
I have understood the importance of the questionnaire. I understand that although every reasonable precaution will be taken to ensure complete safety during this study, I understand that any exercise carries with it an element of risk, however small. I have had the opportunity to discuss the procedures involved in the fitness assessment, and understand that I can withdraw from it at any time. I agree to allow my world daughter to participate in the investigation described.

Signed by caregiver: __________________________ Date: __________________________

Adapted from: http://www.fqpt.co.uk/PARQ.pdf