CHAPTER 4

DISCUSSION
4.0 Discussion

In accordance with previous studies (Eston et al., 2005, 2006, 2008; Faulkner et al., 2007) the current data lend encouraging support for the validity of predicting $\dot{V}O_{2max}$ from perceptually regulated, graded sub-maximal exercise. More specifically, the perceptual RPE range of 9-15 provided a reliably accurate and valid data range by which to estimate participant $\dot{V}O_{2max}$ following extrapolation to the appropriate effort factor (RPE19 or RPE20).

4.1 Oxygen Uptake and RPE

Results from the current study illustrate a strong relationship between RPE and oxygen uptake. Oxygen uptake increased in response to ascending RPE levels from 9-15 and hence incremental intensities. Increases in mean oxygen uptake between ascending RPEs revealed within the current study have been compared with relative % $\dot{V}O_{2max}$ to RPE proportional measures (table 4.1). Mean $\dot{V}O_{2max}$ was calculated at 198 bpm, thus provided a baseline measure for the tabular analysis.
Table 4.1  Summary of the relationship between mean maximal oxygen uptake (ml·kg⁻¹·min⁻¹) at respective RPE levels. Recommended % $\dot{V}O_{2,max}$ (ml·kg⁻¹·min⁻¹) range in relation to each RPE Level is provided.

<table>
<thead>
<tr>
<th>RPE Level</th>
<th>Trial 1 $\dot{V}O_{2,max}$ (ml·kg⁻¹·min⁻¹)</th>
<th>Trial 2 $\dot{V}O_{2,max}$ (ml·kg⁻¹·min⁻¹)</th>
<th>Trial 3 Heart Rate (ml·kg⁻¹·min⁻¹)</th>
<th>Mean $\dot{V}O_{2,max}$ (ml·kg⁻¹·min⁻¹)</th>
<th>Recommended $\dot{V}O_{2,max}$ Range (ml·kg⁻¹·min⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>16.6</td>
<td>14.9</td>
<td>15.6</td>
<td>15.7</td>
<td>&lt;9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(&lt;20% $\dot{V}O_{2,max}$)</td>
</tr>
<tr>
<td>11</td>
<td>21.2</td>
<td>18.5</td>
<td>19.2</td>
<td>19.6</td>
<td>14.4-18.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(30-39% $\dot{V}O_{2,max}$)</td>
</tr>
<tr>
<td>13</td>
<td>28.5</td>
<td>27.1</td>
<td>24.5</td>
<td>26.7</td>
<td>24-28.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(50-59% $\dot{V}O_{2,max}$)</td>
</tr>
<tr>
<td>15</td>
<td>36.3</td>
<td>35.1</td>
<td>34.7</td>
<td>35.3</td>
<td>30.7-36.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(64-76% $\dot{V}O_{2,max}$)</td>
</tr>
</tbody>
</table>

Recommended % ranges calculated from data cited by Buckley and Eston (2007).

Table 4.1 illustrates that oxygen uptake increased as a result of incremental RPE production, demonstrating that oxygen uptake increased in conjunction with incremental exercise intensity. Notably, when compared with validated estimates of RPE – $\dot{V}O_{2,max}$ increments, mean values reported from RPE 9 are suggestive of mean overproduction as they were up to 7.6 ml·kg⁻¹·min⁻¹ (trial 1) outside of the estimated range. $\dot{V}O_{2,max}$ reported across RPE 11 were also fractionally above estimate by up to 2.5 ml·kg⁻¹·min⁻¹ (trial 1). However, values improved and approached estimated ranges with practice, thus displaying progression by further familiarisation. However, mean oxygen uptake at RPEs 13 and 15 were comfortably within their estimated range across all trials, thus suggesting that higher intensity exercise heightens sensational aptitude and perceptual awareness.
Therefore, when expressed as proportions of maximal values, RPE levels induced effort productions equating to between 30 – 73% of mean \( \dot{V}_{O_2}^{\text{max}} \).

Due to the strong linear relationship between oxygen uptake and RPE intensity, extrapolation of recorded \( \dot{V}_{O_2} \) values from the perceptual range of 9-15 allowed for effective extrapolation to RPE\(_{19} \) or RPE\(_{20} \) thus yielding estimates of \( \dot{V}_{O_2}^{\text{max}} \) which closely reflected that of the actual \( \dot{V}_{O_2}^{\text{max}} \) values attained from the maximal GXT. \( \dot{V}_{O_2} \) values were extrapolated to both RPE\(_{19} \) and RPE\(_{20} \) due to the trend that the majority of participants reported RPE\(_{19} \) as their maximal RPE. St Clair Gibson et al. (1999) and Faulkner et al. (2007) support this observation by providing evidence that the theoretical RPE of 20 is infrequently reported at volitional exhaustion. Hence, the four \( \dot{V}_{O_2} \) values obtained were more commonly extrapolated to RPE\(_{19} \). This also presents a logical approach with regards to participant/patient safety as underestimation provides a more preventative approach toward any ill-effects of unduly strenuous exercise.

4.2 Trends found between Heart Rate and RPE

As displayed in section 3.1, findings depict a strong linear relationship between RPE and HR.

HR was directly dependent on the rate of work and thus ascended with increments in protocol and at a higher RPE than the previous level. Increases in mean heart rate between ascending RPEs revealed within the current study have been compared with relative %HR\(_{\text{max}} \) to RPE proportional measures (table 4.2). To compare mean heart rate to authentically validated ranges a mean HR\(_{\text{max}} \) needed to be determined from the sample group. To achieve this, the 220 minus age (HR\(_{\text{max}} = 220 - \text{age} \)
technique was used (Buckley, Holmes & Mapp, 1999). Mean HR$_{\text{max}}$ was calculated at 198 bpm.

**Table 4.2** Summary of the relationship between mean heart rate (HR) at respective RPE levels. Recommended % HR$_{\text{max}}$ (bpm) range in relation to each RPE Level is provided.

<table>
<thead>
<tr>
<th>RPE Level</th>
<th>Trial 1 Heart Rate (bpm)</th>
<th>Trial 2 Heart Rate (bpm)</th>
<th>Trial 3 Heart Rate (bpm)</th>
<th>Mean Heart Rate (bpm)</th>
<th>Recommended Heart Rate Range (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>111</td>
<td>107</td>
<td>107</td>
<td>108</td>
<td>&lt;69 (&lt;35% HR$_{\text{max}}$)</td>
</tr>
<tr>
<td>11</td>
<td>125</td>
<td>119</td>
<td>118</td>
<td>121</td>
<td>88-106 (45-54% HR$_{\text{max}}$)</td>
</tr>
<tr>
<td>13</td>
<td>150</td>
<td>142</td>
<td>137</td>
<td>143</td>
<td>123-137 (62-69% HR$_{\text{max}}$)</td>
</tr>
<tr>
<td>15</td>
<td>173</td>
<td>169</td>
<td>166</td>
<td>169</td>
<td>151-164 (76-83% HR$_{\text{max}}$)</td>
</tr>
</tbody>
</table>

Recommended %HR$_{\text{max}}$ ranges calculated from data cited by Buckley and Eston (2007).

It can be observed within table 4.2 that recorded HR had a tendency to be higher than literature states it should be at relative RPE levels. Such a finding would suggest that HR may provide weak accuracy and agreement when attempting to predict $\dot{V}_O^{\text{2max}}$. Such a factor would lend further advocate a predictive method based on the use of $\dot{V}_O^2$ measurements taken at different levels of sub-maximal exercise.

Positively however, table 4.2 shows that heart rates ascended with consecutive RPEs; HR values remained consistent from trial-to-trial with the majority reported within <
5 bpm of the previous trial at corresponding levels. Most saliently, HR values at corresponding RPEs were ≤ from trial-to-trial further demonstrating a learning effect on the participant (habituation).

4.3 Interpreting the Limits of Agreement (LoA) by the “worst case scenario approach”.

In review of the procedures employed, and the outcomes observed in the current study, the data revealed compares positively with past studies on the same theme of research. By adopting Nevill and Atkinson’s (1997) “worst case scenario approach”, also entertained by Buckley et al. (2004), the third and final production trial yielded favourable results as deemed by the 95% LoA technique. The third production trial provided the closest mean $\dot{V}O_{2\text{max}}$ prediction in comparison to the actual mean $\dot{V}O_{2\text{max}}$ value when determined from the $\dot{V}O_2$ values obtained from the four RPE intensities (9, 11, 13, and 15). Therefore, as the 95% LoA comparison was calculated as $–0.6±7.1 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, the worst case scenario range for the majority of the sample was calculated to $6.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ below the criterion $\dot{V}O_{2\text{max}}$ score and $7.7 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ above. Table 4.3 provides comparable details of previous studies investigating the same theme. Table 4.3 therefore illustrates that current predictions yielded from the RPE range 9-15 are favourable in comparison to recent findings using the same perceptual range, and also fair well when compared to more complete RPE ranges such as 9-17.
Table 4.3  Outlines previous, similar themed studies, providing comparative protocol, LoA and “worst case scenario” information.

<table>
<thead>
<tr>
<th>Author/s</th>
<th>Description of Study</th>
<th>RPE range</th>
<th>Order of Trial</th>
<th>Values extrapolated to: RPE₁₉ or RPE₂₀</th>
<th>Best LoA</th>
<th>“Worst Case Scenario” values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buckley et al. (2004)</td>
<td>Quantified the validity of data from the Chester Step test against that of a treadmill criterion.</td>
<td>N/A</td>
<td>2nd of 2</td>
<td>N/A</td>
<td>-1.9±7.4 ml·kg⁻¹·min⁻¹</td>
<td>5.5 ml·kg⁻¹·min⁻¹ – 9.3 ml·kg⁻¹·min⁻¹</td>
</tr>
<tr>
<td>Eston et al. (2005)</td>
<td>Investigation similar to current study, however a cycle ergometer provided the exercise mode.</td>
<td>9-17</td>
<td>2nd of 3</td>
<td>RPE₂₀</td>
<td>0.2±4.9 ml·kg⁻¹·min⁻¹</td>
<td>4.7 ml·kg⁻¹·min⁻¹ – 5.1 ml·kg⁻¹·min⁻¹</td>
</tr>
<tr>
<td>Eston et al. (2006)</td>
<td>Study similar to that of Eston et al. (2005), using cycle ergometry.</td>
<td>9-15</td>
<td>2nd of 2</td>
<td>RPE₂₀</td>
<td>-0.37±10.6 ml·kg⁻¹·min⁻¹</td>
<td>10.2 ml·kg⁻¹·min⁻¹ – 10.9 ml·kg⁻¹·min⁻¹</td>
</tr>
<tr>
<td>Eston et al. (2006)</td>
<td>As above.</td>
<td>9-17</td>
<td>2nd of 2</td>
<td>RPE₂₀</td>
<td>-0.47±7.44 ml·kg⁻¹·min⁻¹</td>
<td>6.9 ml·kg⁻¹·min⁻¹ – 7.9 ml·kg⁻¹·min⁻¹</td>
</tr>
<tr>
<td>Faulkner et al. (2007)</td>
<td>Performed a similar study to Eston et al. (2005; 2006) using cycle ergometry to compare predictions between an active and sedentary population.</td>
<td>9-15</td>
<td>3rd of 3</td>
<td>RPE₁₉</td>
<td>1.7±11.2 ml·kg⁻¹·min⁻¹</td>
<td>10.0 ml·kg⁻¹·min⁻¹ – 12.9 ml·kg⁻¹·min⁻¹</td>
</tr>
<tr>
<td>Faulkner et al. (2007)</td>
<td>As above.</td>
<td>9-15</td>
<td>3rd of 3</td>
<td>RPE₂₀</td>
<td>-0.9±11.8 ml·kg⁻¹·min⁻¹</td>
<td>10.9 ml·kg⁻¹·min⁻¹ – 12.7 ml·kg⁻¹·min⁻¹</td>
</tr>
<tr>
<td>Faulkner et al. (2007)</td>
<td>As above.</td>
<td>9-17</td>
<td>3rd of 3</td>
<td>RPE₁₉</td>
<td>0.4±8.4 ml·kg⁻¹·min⁻¹</td>
<td>8.0 ml·kg⁻¹·min⁻¹ – 8.8 ml·kg⁻¹·min⁻¹</td>
</tr>
<tr>
<td>Faulkner et al. (2007)</td>
<td>As above.</td>
<td>9-17</td>
<td>3rd of 3</td>
<td>RPE₂₀</td>
<td>-2.7±9.2 ml·kg⁻¹·min⁻¹</td>
<td>6.5 ml·kg⁻¹·min⁻¹ – 11.9 ml·kg⁻¹·min⁻¹</td>
</tr>
<tr>
<td>Eston et al.</td>
<td>Similar theme as previous</td>
<td>9-15</td>
<td>2nd of 3</td>
<td>RPE₂₀</td>
<td>4.6±12.4</td>
<td>7.8 ml·kg⁻¹·min⁻¹</td>
</tr>
</tbody>
</table>
On analysis of the data displayed in table 4.3, there is only one entry that displays a narrower LoA both above and below its criterion \( \dot{V}_\text{O}_{2\text{max}} \) value than the current study, this is from the study by Eston et al. (2005) (shaded row) which predicts \( \dot{V}_\text{O}_{2\text{max}} \) from RPE using cycle ergometry. However, these LoA comparisons are derived from using a broader RPE range than that of the current study, 9-17 compared to 9-15 for the respective studies. It has been strongly speculated from previous literature that this is likely to be due to greater sensations of exertion aroused by higher intensity exercise which makes feelings of strain and fatigue much more apparent, and thus easier to judge in comparison to perceptual rating scale (Eston & Williams, 1988; Carter et al., 2000; Buckley et al., 2004; Eston et al., 2008). However, results from the current study compare favourably with those provided by Faulkner et al. (2007) and Eston et al. (2008) (see table 4.3) which attempt to predict \( \dot{V}_\text{O}_{2\text{max}} \) from perceptually graded exercise using both the 9-15 and 9-17 RPE ranges. Reasons for this contrast may lie within the selected sample populations selected of those studies as Faulkner et al. (2007) recruited participants categorised as sedentary, and similarly Eston et al. (2008) recruited even numbers of sedentary as well as active participants. Explanation has been offered as to why sedentary individuals may struggle to accurately perceive exertion; firstly a lack of exercise experience may influence underproduction due to minimal internal associations with past feelings of exertion. Participants therefore have limited grounds for comparison, hence production trials.
may act as a learning curve rather than an accurate appraisal of current sensations (Faulkner et al., 2007; Eston et al., 2008; Gearhart, 2008). Additionally, as participants are fully appraised of test protocol, and by the second trial have experience of what to expect, then they may opt to “hold back” and employ pacing strategies in the knowledge of what sensations are to come at the subsequent (higher) RPE stages, thus adopting a mind-set of energy conservation for the latter, more strenuous stages (Hampson, Gibson, Lambert & Noakes, 2001; Noakes, 2004; St Clair Gibson., 2006; Faulkner et al., 2007).

In the current study however, cases of underproduction were observed when comparing predicted \( \dot{V}_{O2\text{max}} \) values to the actual \( \dot{V}_{O2\text{max}} \). This may have occurred due to the use of conscious pacing strategies, or perhaps a more internal and subconscious pacing effect. It has been hypothesized that work rate may be centrally controlled in an anticipatory manner to regulate metabolic and biomechanical demands; a regulatory mechanism operating outside of conscious control; such a process is termed ‘teleoanticipation’ (Ulmer, 1996; cited in Eston et al., 2006:536). Also, there were instances of overproduction at the initial RPEs (such as 9 and 13) which may have led to a marginally lower predictive accuracy of \( \dot{V}_{O2\text{max}} \), a scenario also observed by Eston et al. (2008).

In contrast, there were a small number of predictive trials within the current study which overproduced at all, or the majority of RPE stages, thus producing a higher predictive accuracy of \( \dot{V}_{O2\text{max}} \). This observation was largely confined to trial 1 and could be explained by a participant’s desire to produce their best possible effort as Eston et al. (2008) would concur; or despite constant reinforcement of the aims and
instructions regarding the testing, the procedural requirements of the participants may have only become apparent after the initial trial/s.

As hypothesised, predictive accuracy improved from trial-to-trial. Margins of underproduction or overproduction were minimised from trial-to-trial as predictive $\dot{V}O_{2\text{max}}$ values for the majority of the sample encroached those of the actual $\dot{V}O_{2\text{max}}$. Consecutive trial-to-trial predictive accuracy displayed consistent mean progression and improvement throughout the three trials due to the enhanced familiarisation and habituation that came with experience and practice, trends concurring with the findings of Lamb et al. (1999), Buckley et al. (2004), Eston et al. (2006) and Faulkner et al. (2007). Thus, inter-trial predictive improvement from the current study endorses an essential repeatability which is salient to the reliability of employing such a method within an exercise prescription for a clinical population. Therefore, the success of the participants at regulating their exercise intensity with consistent accuracy during continuous, incremental production trials complies with previous findings on perceptual effort regulation (Ceci & Hassmén, 1991; Dunbar et al., 1992; Eston & Williams, 1988; cited in Faulkner et al., 2007; Marriott & Lamb, 1996; Kang et al., 1998; Eston et al., 2005; Eston et al., 2006; Faulkner et al., 2007; Eston et al., 2008).

Referring once again to table 4.3, it is clear that the use of perceptually regulated treadmill exercise through an RPE range of 9-15 within the current study provides closer LoA comparisons between predicted and actual $\dot{V}O_{2\text{max}}$ values than past studies applying the same RPE range within cycle ergometry testing. This finding may be as a result of an effective combination of exercise mode and protocol; treadmill
exercise incorporates whole body locomotion thus sharing workload perhaps more evenly between central and peripheral factors, additionally increments in gradient coupled with increases in speed challenges the skeletal muscle of the lower extremities, thus evoking greater sensations of local effort and heightening aptitude to perceptions of exertion (Lamb, 1996; Carter et al., 2000; Buckley et al., 2004).

The results revealed that the RPE ranges of 9-13 and 9-11 led to unacceptable, and often significant underestimations of \( \dot{V}O_{2\text{max}} \). To elaborate, the greatest underestimations calculated from the perceptual RPE ranges 9-13 and 9-11 were generated from values reported from third and final production trial (9.8 and 14 ml·kg\(^{-1}\)·min\(^{-1}\) below actual \( V_{O2\text{max}} \), respectively). This finding is in stark contrast to the predictions reported when using the 9-15 range. Furthermore, the closest predictions to actual \( \dot{V}O_{2\text{max}} \) when using the 9-13 and 9-11 range were generated from the first trial and provide poor worst case scenario ranges of 18.6 – 18.9 ml·kg\(^{-1}\)·min\(^{-1}\) and 16.9 – 32.2 ml·kg\(^{-1}\)·min\(^{-1}\), respectively. These trends expose the RPE ranges of 9-13 and 9-11 as inaccurate, unreliable and invalid. Such findings tie in with observations made in table 4.1 which highlight that mean oxygen uptake at RPEs 9 and 11 of the current study are higher than relative estimates presented in current literature. It is suggested that the under-predictive and inaccurate nature of the narrower RPE ranges of 9-13 and 9-11 is as a consequence of RPE being more strongly correlated with physiological markers of exercise such as \( \dot{V}O_2 \), at higher intensity workloads (Eston & Williams, 1988; cited in Faulkner et al., 2007).
Referring back to the study by Eston et al. (2005), their best LoA was calculated from an RPE range 9-17, it is therefore to be expected that trial-to-trial reliability expressed in table 4.3 has to be stronger than that calculated from the RPE range of 9-15 from the current study. This observation is therefore illustrated in table 4.4.

Table 4.4. Comparative analysis of the consistency of \( \dot{V}_{O_{2\max}} \) predictions over three production trials using the full ranges of RPE adopted within the current study (RPE 9-15) and that of Eston et al. (2005).

<table>
<thead>
<tr>
<th>Study</th>
<th>RPE range</th>
<th>Trial 1 – Trial 2</th>
<th>Trial 2 – Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current study</td>
<td>9-15</td>
<td>0.90±12.3</td>
<td>1.72±8.50</td>
</tr>
<tr>
<td>Eston et al. (2005)</td>
<td>9-17</td>
<td>-1.3±6.1</td>
<td>-1.3±4.4</td>
</tr>
</tbody>
</table>

Table 4.4 illustrates that there is only marginal differences in trial-to-trial consistency when comparing LoA calculations using the 9-17 RPE adopted by Eston et al. (2005) and the 9-15 RPE range employed by the current study. In analysis of the differences in procedures and samples adopted by Eston et al. (2005), a sample group of physically active males were specifically recruited to participate in the investigation. As this sample group were selected on the basis of qualifying as ‘physically active’, it can be assumed that those participants were relatively fit and had good prior experience of various levels of physical exertion. Thus, it was logical to extrapolate linear regression equations to RPE\(_{20}\) as participants were likely to perform relatively well in comparison to a more sedentary sample body. As the current study required participants to be healthy and free from disease, and not necessarily fit or physically active, then a lower mean \( \dot{V}_{O_{2\max}} \) might be expected when compared to the findings
of Eston et al. (2005). This was in actual fact the case as Eston et al. (2005) recorded the highest actual mean group $\dot{V}O_{2\text{max}}$ of 48.8 ml·kg$^{-1}$·min$^{-1}$, whereas the actual mean group $\dot{V}O_{2\text{max}}$ recorded in the current study was 48.0 ml·kg$^{-1}$·min$^{-1}$. Hence, it could be hypothesised that perceptually regulated exercise employing the RPE range of 9-17 would reveal even closer LoA comparisons between actual and predicted $\dot{V}O_{2\text{max}}$ as well as narrower consistency between trials due to greater sensations of exertion becoming apparent to the participant at higher RPE levels. Eston et al. (2008) would be inclined to concur with such a statement as they suggested that under-prediction of $\dot{V}O_{2\text{max}}$ was associated with the removal of RPE 17 from the predictive analysis, and instead using the 9-15 RPE range.

### 4.4 Analysis of Correlation coefficients

The use of both 95% LoA and correlation coefficients (ICC and Pearson) compliment each other well. Agreement of within-subject variability provided by LoA analysis from the application of the 9-15 RPE range supports the measures of relationship and mean difference determined by the relevant correlation coefficients. The RPE range 9-15 was certainly the most successful in terms of $\dot{V}O_{2\text{max}}$ prediction accuracy and trial-to-trial consistency. For example, the reliability of $\dot{V}O_{2\text{max}}$ prediction from trial 3 when using the RPE range 9-15 received the high Pearson correlation of 0.853; this $R$ value supported the corresponding LoA of -0.6±7.1 effectively. Additionally, when assessing trial 2 to trial 3 consistency (again using the 9-15 RPE range) high ICC
and Pearson correlations of 0.837 and 0.848 respectively compliment the trial-to-trial LoA of 1.72±8.50 favourably and suggest a strong repeatability factor.

However, as discussed earlier, RPE ranges 9-13 and 9-11 did not fair well in terms of agreement or reliability. The perceptual range of 9-13 revealed weaker Pearson correlations indicating modest predictive reliability values of 0.670, 0.534 and 0.488 alongside considerably lower LoAs than the 9-13 range as -0.19±18.8 from the first trial proving the closest. Moreover, trial-to-trial consistency declined from a high correlation \( (R = 0.571) \) between trials 1 and 2, to a modest correlation \( (R = 0.569) \) between trials 2 and 3.

Furthermore, when taken at face value the perceptual RPE range of 9-11 can be rejected as a valid means of predicting \( \dot{V}O_{2\text{max}} \) from sub-maximally graded exercise offering its closest mean predicted value 7.6 ml·kg\(^{-1}\)·min\(^{-1}\) below that of the actual mean \( \dot{V}O_{2\text{max}} \); an assumption which can be confirmed by the low to very low ICCs (0.31, 0.01, and 0.08) and the modest to very low Pearson correlation coefficients (0.51, 0.04, and 0.19) for trials 1, 2, and 3 respectively.

4.5 **Familiarisation with the RPE Scale and Test Protocol: Trends in Habituation.**

As touched on in section 4.3, repeatability and predictive accuracy improved with protocol familiarity when calculating data from RPE range 9-15, thus LoA ranges narrowed with successive trials (1-3) and ICCs and Pearson correlations also improved consistently. Such findings concur with the predictive comparisons and consistency measures revealed by Faulkner et al. (2007) which showed that familiarisation continued from the first to the last trial.
In regards to the current study, the initial production trial could be viewed as a practice trial and served the purpose of familiarising and habituating participants with the exercise mode, test protocol and the Borg scale, therefore production trials 2 and 3 were outlined as the key elements in terms of performance accuracy and thus reliability (the purpose and actual function of the initial trial will be discussed further later).

It is worthy of mention that the reason the perceptual intensities of 9, 11, 13, 15 on Borg’s RPE scale were chosen was merely due to the fact that they represent a wide range of efforts (from very light to hard (heavy)) and are accompanied by verbal descriptors to help participants accurately associate their feelings of exertion with their psychophysical feedback cues. An RPE of 15 was selected as the highest sub-maximal anchor to exercise to, in consideration of the protocol’s application within a clinical setting; as a precaution it was theorised that an RPE beyond 15 may jeopardise patient welfare by imposing unnecessary weight-bearing on the joints in the lower limbs when using the treadmill. Furthermore, RPEs above 15 may place unnecessary strain on the cardiorespiratory system of a cardio-selective population (Eston et al., 2005; Eston et al., 2006; Faulkner et al., 2007; Eston et al., 2008). In agreement with suggestions proposed by Eston et al. (2008) it would appear feasible to apply RPE 9 as a suitable warm-up intensity as well as using it within a $\dot{V}O_{2\text{max}}$ prediction protocol if desired. Such a modification would impact positively by facilitating familiarisation, lowering cost of testing and reducing the overall time of exertional effort by the participant. A modification of this nature may help to tighten consistency and accuracy of predictive trials by offsetting pacing strategies employed
by participants whereby they are aware of the parameters of each trial, and thus are able to approximate the duration of each RPE level and total exercise bout. Therefore, lessening the duration of continuous and prolonged exertion by substituting the warm-up phase with RPE 9 may deter participants from adopting pacing strategies.

4.6 Limitations of the study

It should be highlighted that for such an investigation Atkinson and Nevill (1998) would recommend that a sample size of 40 or more would have been suitable due to the nature of the statistical procedures employed. Such a recommendation is proposed as the limits of agreement (LoA) technique used in the statistical analysis requires all data to be extrapolated and therefore a large sample population is said to be favoured for the purposes of improved reliability (Atkinson and Nevill, 1998). The use of a larger sample may have reduced the impact of the few discrepancies observed providing the majority of the population conformed to an acceptable accuracy. However, due to the timescale imposed upon the study and with consideration to matters of practicality, conducting 200 individual tests was highly unrealistic, and hence the proposed sample size was halved. Furthermore, past studies by Eston et al. (2005), Eston et al. (2006) and Eston et al. (2008) have conducted studies of similar design to this one using sample sizes below twenty ($n = 10, 19, \text{ and } 13$, respectively), and all claiming acceptable agreement, reliability and validity.
It should also be noted that an initial group of 24 participants were inducted into the programme; however six were unable to complete the study due to unforeseen circumstances.

Furthermore, subjects were asked to abstain from consuming certain substances or performing strenuous activities within the 24 hours before a testing session. Participants were also requested to follow identical routines in the 24 hours prior to testing, in regards to diet, sleep and exercise. However, it is impossible to know how closely these instructions were followed and what impact any variation in routine may have had on production, and indeed estimation testing. In future, it may be helpful for researchers to provide a basic log sheet to allow both participants and researcher/s to keep track of habitual events throughout the study.

Moreover, one participant (P1) claimed they were suffering from a chest infection; P1 was told that they would not be allowed to perform the test on that day and asked to report back in one week to re-start testing. In this case, P1 completed testing in 14 days instead of the proposed ten day period.

Additionally, there were two participants (P2 + P3) who expressed fatigue during their second trials and asked if the test was almost finished; this occurred during RPE 15 on both occasions and may have suggested that those participants were overestimating their perception of exertion.

Moreover, one participant (P4) expressed an absolute distain for the face mask, claiming they felt claustrophobic. P4 was given the option to stop but chose to persevere each time, such a situation may act to distort ratings of exertion and influence pacing strategies and an under-production, especially at the higher
intensity RPE’s (Hampson, Gibson, Lambert & Noakes, 2001; Noakes, 2004; St Clair Gibson., 2006).

Lastly, a considerable number of participants were unsure whether to walk or run at RPE level interchanges, particularly the step change between RPE 11 and 13. Green et al. (2002:12) suggests that this issue presents a “grey zone” based on individual preference and may be capable of influencing production accuracy between lower and higher intensities. To this end, ACSM (1995) suggest that this grey zone is likely to occur between the paces of 50 to 100 m∙min⁻¹ (walking) and >134 m∙min⁻¹ (running). Dunbar et al. (1992) states that a combination of walking and running within an RPE level may cause perceptual signal strength to become confounded.

4.7 Implications for RPE Guided Exercise Prescription

The healthy young participants in this study were able to produce prescribed RPE intensities (9-15) with increasing accuracy and reliability when performing incremental continuous treadmill exercise. Increasing habituation and repeatability from trial-to-trial produced valid and reliable estimates of $\dot{V}_{O_2}{max}$ which compared favourably with actual $\dot{V}_{O_2}{max}$ values when using the perceptual 9-15 range. 95% LoA analysis complimented bi-variate correlation reliability by yielding acceptable agreement between predicted and actual values, for example the LoA of -0.6±7.1 ml·kg⁻¹·min⁻¹ was reported from trial 3 using the 9-15 range. This was strongly reinforced by LoA trial-to-trial consistency analysis which provided a 95% LoA of 1.72±8.50 ml·kg⁻¹·min⁻¹ when using the 9-15 range between trials 2 and 3. LoA effectively communicated strong to weak agreement from and between trials when
assessing the three perceptual ranges of 9-15, 9-13 and 9-11, and thus complying well with varying strengths of correlation as determined by ICCs and Pearson correlation coefficients.

RPE production mode using the treadmill can produce repeatable and accurate estimates of $\dot{V}O_{2\text{max}}$ when incorporating the higher ratings of exertion, however it needs to be determined as to whether such protocols using a treadmill are clinically acceptable. The treadmill production protocol used in the current study has achieved closer 95% LoAs than previous studies using cycle ergometry when comparing values reported from the same perceptual ranges. Hence, Eston et al. (2005) concurs that decisions regarding which perceptual ranges to adopt, as well as selection of exercise mode should be guided by the nature of the population.

Importantly, and as advocated by Faulkner et al. (2007), it is important to provide close supervision of exercise trials, especially when testing sedentary individuals to constantly reinforce test objectives and maintain their concentration at the task at hand. This facilitates exercise adherence as it helps participants become more attuned to sensations of exertion and thus regulate their exercise intensity accurately (Faulkner et al., 2007).

4.8 Recommendations for Future Research

Performing a similar study using a larger sample group ($n = 40$), if testing proves reliable it would add more power to results by narrowing the 95% LoA, further minimising any small discrepancies.

Moreover, As this study was the first to assess the test-retest reliability and validity of using perceptually guided, graded treadmill exercise to predict $\dot{V}O_{2\text{max}}$ then it
would be logical to recommend future testing using a variety of populations; for example trained athletes and sedentary individuals to provide an insight into the influence exercise experience and activity level has on the RPE production mode, the elderly may be observed, and gender differences could also be assessed by future research.

Recommendations could also be made to alter test protocol. Such adaptations might consist of adding RPE 17 to the production trials which literature suggests would heighten sensations of exertion and allow for more accurate perceptions, thus tightening LoAs and enhance test-retest reliability (Faulkner et al., 2007). Furthermore, RPE levels could be prescribed in a random order in each production trial; this may require an intermittent protocol with recovery periods between each RPE stage to allow for physiological variables to return to a normal range (Eston et al., 2005). If test-retest $\dot{V}O_2$ proved to be acceptably consistent then validity and reliability of the role of RPE in $\dot{V}O_{2max}$ estimation would be greatly improved.

Lastly, it would appear logical to remove a warm-up phase from the protocol and substitute it with RPE 9 (the initial test level) in order to reduce prolonged exertion and maximise reliability (Eston et al., 2008).

**4.9 Conclusion**

In conclusion, the data interpreted from this study provides support for a perceptually guided GXT capable of predicting cardiovascular fitness with acceptable agreement in a young and healthy sample population. With increasing accuracy and reliability participants performed three identical production trials on a treadmill using the RPE range of 9-15. Agreement improved with practice and the best LoA
agreement between predicted and actual $\dot{V}O_{2\text{max}}$ of -0.6±7.1 ml·kg$^{-1}$·min$^{-1}$ was
produced from the third and final trial and provided an impressive worst case
scenario range of 6.5 ml·kg$^{-1}$·min$^{-1}$ below the criterion $\dot{V}O_{2\text{max}}$ score and 7.7 ml·kg$^{-1}$·min$^{-1}$ above. Strong trial-to-trial consistency was therefore observed between trial
2 and 3 (1.72±8.50) when using the RPE range of 9-15. High correlation coefficients
further echoed the strength of relationship found between trials and between
estimated and actual $\dot{V}O_{2\text{max}}$ values.

However, the narrower perceptual ranges of 9-11 and 9-13 provided poor estimates
of $\dot{V}O_{2\text{max}}$ which worsened from trial-to-trial, this was attributed to weaker
sensations of exertion which proved harder to perceptually interpret.

Thus, sub-maximal, perceptually guided, graded treadmill exercise protocol holds
acceptable validity and reliability by which to predict $\dot{V}O_{2\text{max}}$, when an appropriate
RPE range is selected. Such a utility may provide a superior predictive method than
other physiological measures which may become distorted by environmental factors,
medical condition or medication.