ORIGINAL ARTICLE

Oxygen saturation response to exercise in healthy pregnant women: a simple protocol and normal range

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Summary: Measurement of oxygen saturation on excercise, using a pulse oximeter, has been advocated in the assessment of women with shortness of breath in pregnancy. However, there is currently no standard protocol for this. The aims of this study were to determine the normal range for oxygen saturation at rest and on moderate exercise in healthy women from 24 weeks gestation and to evaluate a simple, widely applicable exercise protocol in which women walked at their own pace for 100 metres then up two flights of stairs. The protocol achieved 60–85% maximum predicted heart rate in 99% of women at a median gestation of 31^{+3} weeks, with a wide range of Hb and BMI. There was a mean 0.3% fall in oxygen saturation on exertion but oxygen saturation did not fall below 95% in any of the women.

Keywords: physiology, exercise, oxygen saturation, normal pregnancy

INTRODUCTION

Some degree of shortness of breath is very common in pregnancy, indeed it may be considered to be physiological. However, women attending with shortness of breath present a diagnostic challenge as this may also be the presenting symptom of significant cardiac or respiratory disease. Those conditions causing hypoxia carry a worse prognosis for mother and fetus[1] so it is important to differentiate 'physiological' from 'pathological' shortness of breath. However, at the same time clinicians must avoid unnecessary investigations, particularly those involving ionizing radiation. What is needed is a simple predictor of important disease.

In the non-pregnant patient, measuring oxygen saturation with a pulse oximeter (SpO_2) at rest and on exertion, as an indicator of arterial oxygen saturation (SaO_2), is commonly advocated as a screening device.[2] The normal range is well established in men at sea level, with resting SaO_2 being 95% or greater. Although extreme exertion in highly motivated athletes may lower SaO_2,[3] moderate exercise does not cause a fall in SaO_2.[4] A fall in SpO_2 of greater than 4% on exertion suggests a significant gas exchange abnormality, although it is important to ensure motion artefacts are avoided and SpO_2 may not accurately represent SaO_2 in conditions such as very low SaO_2, below 70%, or hypotension with poor peripheral perfusion.[2]

The use of pulse oximetry on exertion has long been recommended in pregnant women[5] but there are few data on the normal range for oxygen saturation at rest and on exertion, and there is no standard exercise protocol to deliver an appropriate cardiovascular challenge in pregnant women.

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The aims of this study were firstly to establish the normal range for SpO_2 on moderate exertion in healthy pregnant women, to determine whether it is comparable with non-pregnant values. The second aim was to evaluate a simple, widely applicable exercise protocol to deliver an appropriate moderate cardiovascular challenge to women in the second and third trimesters of pregnancy.

METHODS

Subjects and protocol

The study protocol was approved by the local ethics committee. One hundred healthy women in the second or third trimester of pregnancy were recruited from the ante-natal clinic. Women were excluded if they had given a history of significant cardiac or respiratory disease or if they were unable to give informed consent.

Routine data were recorded from the ante-natal records, including age, gestation, haemoglobin concentration, body mass index (BMI), smoking status and whether singleton or twin pregnancy. Following the study, fetal outcome was recorded including survival, gestation at delivery and birthweight.

The exercise protocol was carried out at Princess Royal University Hospital, Bromley, UK, at an altitude of approximately 100 m above sea level. A pulse oximeter (Pulsox – 300i, Konica Minolta, Tokyo, Japan) was used to measure SpO_2 with the probe on a finger, having removed nail varnish where necessary. Measurements of SpO_2 and pulse rate were taken when the women were standing at rest. The women were then exercised at their normal walking pace, so they could still manage to talk, with a walk initially on the flat for 100 m then immediately up two flights of stairs of 12 steps each. Pulse rate and SpO_2 were recorded continuously during exercise and the recovery period. Heart rate was recorded both as an absolute value and as a percentage of the maximum predicted heart rate (calculated as 220 minus age).

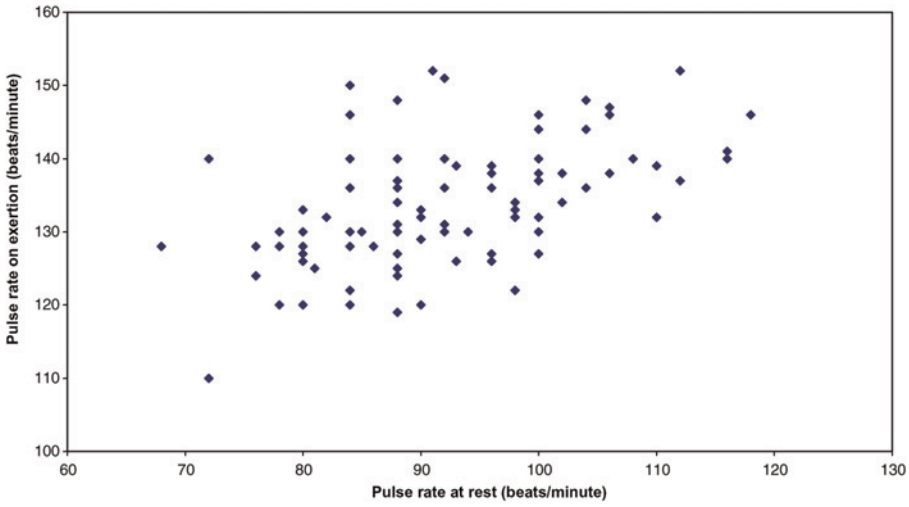

Figure 1 **Graph of pulse rate on exertion against pulse rate at rest**

Statistical analysis

A paired *t*-test was used to test whether pulse rate and oxygen saturation changed significantly on exercise compared with resting values. Normally distributed values are expressed as mean ± SD. The range is also given where this is clinically relevant.

RESULTS

Subjects

One hundred women were recruited, aged 31.0 ± 6.8 (range 15–47) years. Median (range) gestation was 31^{+3} (24^{+0}–40^{+6}) weeks. Mean haemoglobin concentration: 11.7 ± 1.2 (range 7.9–13.9) g/dL. Mean BMI: 27.1 ± 2.9 kg/m^2. There were nine current smokers and 26 ex-smokers. None of the women had a history of significant cardiac or respiratory disease. Five of the women were carrying twin pregnancies.

Of the 100 women, 99 went on to have a live birth. Birthweights were in the expected range with three babies born below the third centile weight for gestation.

Heart rate response

The resting pulse rate was 91.8 ± 10.4 beats/minute. Pulse rate at peak exercise was 133.6 ± 8.2 beats/minute, representing a 46% increase from baseline and an absolute change of 41.8 beats/minute (95% confidence interval [CI] for difference 39.9–43.6, $P < 0.001$) (Figure 1). The peak heart rate expressed as a percentage of maximum predicted was 70.9 ± 4.7%, with a range from 58% to 84%. This is demonstrated in Figure 2, showing the number of women achieving each value of percentage maximum predicted heart rate. The results are normally distributed, with the majority of women achieving between 65% and 75% maximum predicted heart rate on exercise. In only one woman did the protocol fail to achieve 60% of maximum predicted heart rate. This woman had a

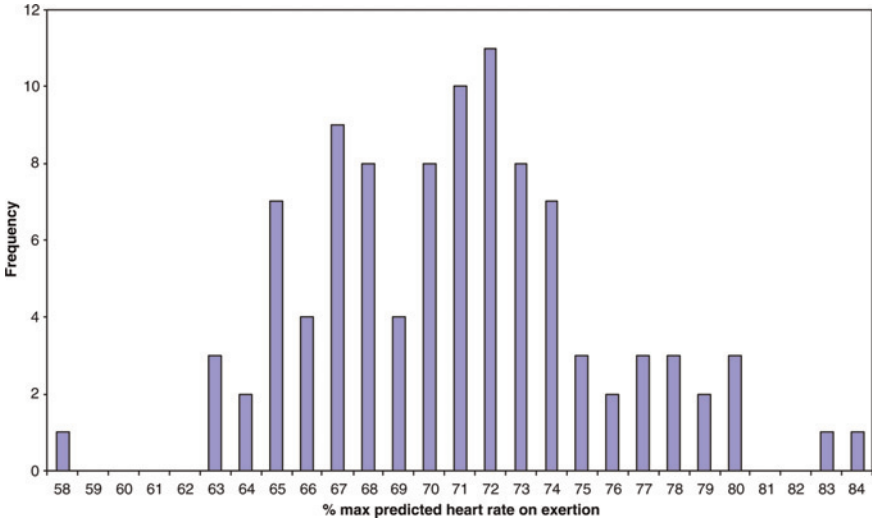

Figure 2 **Peak pulse rate expressed as percentage of maximum predicted heart rate**

high degree of athletic training and for her the protocol was too easy. As demonstrated in Figure 3, those women with lower resting heart rates experienced a greater rise in heart rate.

Oxygen saturations

Mean oxygen saturation at rest was 98.0 ± 0.95% (range 96–100%). At peak exercise oxygen saturation was 97.7 ± 1.0% (range 95–100%). The mean fall in % oxygen saturation was 0.32 (CI for fall in % oxygen saturation 0.17–0.47, $P < 0.001$). In no woman did oxygen saturation fall below 95%. Among current smokers the oxygen saturation at peak exercise was 97.0 ± 0.7%.

DISCUSSION

Measurement of oxygen saturation on exertion is commonly used in the assessment of women with shortness of breath during pregnancy. However, for this to be a useful, objective test it is important to know the oxygen saturation response to a defined cardiovascular challenge in normal pregnant women and to have a standard protocol to deliver an appropriate rise in heart rate. It has previously been found that in healthy non-smoking women, resting oxygen saturation remained at least 97% during pregnancy.[6] A study of 40 healthy women at a mean gestation of 25 weeks found that prolonged low-impact aerobic exercise at a level of 70% maximum predicted heart rate caused a small fall in oxygen saturation but this did not fall below 95%.[7] However, these small studies do not provide a normal range for the oxygen saturation response to moderate exertion after 24 weeks' gestation. Our study demonstrates that oxygen saturation in healthy women during the second and third trimesters of pregnancy is normally greater than or equal to 95% at sea level, in keeping with the normal value in men. On moderate exertion, defined as a rise in heart rate to 60–80% of maximum predicted heart rate, the oxygen saturation fell as seen previously[7] but the fall was only 0.3% and does not appear to be clinically significant. These data suggest that a healthy pregnant woman, without significant cardiac or respiratory disease, is unlikely to have an oxygen saturation of less than 95% on moderate exertion.

This study does not address the oxygen saturation response to exercise in women with cardiopulmonary disease. In the non-pregnant population, desaturation of greater than 4% during exercise suggests a gas exchange abnormality with underlying cardiopulmonary pathology such as pulmonary fibrosis, emphysema, cardiac failure or pulmonary hypertension.[2] We cannot conclude that the absence of a fall in oxygen saturation excludes such an abnormality and further work is required to assess the sensitivity and specificity of this test. However, it is likely from these data that, as in the non-pregnant population, a fall below 95% saturation would be suggestive of a gas exchange abnormality, since it was not seen in this normal population. With the older generation of pulse oximeters there was a high rate of error due to motion artefact. More recent models, such as the one used in this study, have a much lower error rate[8] and pulse oximetry is routinely used in exercise laboratories, but clinicians must still be aware of the possibility of motion artefact.

Although some women with serious cardiac or respiratory disease will have oxygen saturations below 95% at rest, in others exercise may be necessary to demonstrate a fall in oxygen saturation. There is no agreed intensity of exercise required to reveal an abnormality. It is likely that more intense exercise will have a higher yield, but many pregnant women will not wish to undergo high-intensity exercise. Moderate exercise is safe in pregnancy[9] and it has been recommended that a maximal heart rate of 60–70% maximum predicted is appropriate for women who were previously sedentary and 60–90% maximum predicted for those who were fit prior to pregnancy.[10] The value of 60–80% maximum predicted heart rate was chosen as the target in our study in order to provide a significant cardiovascular challenge, likely to reveal any abnormality, while avoiding over-exertion. Allowing women to walk at their own pace, so they were able to talk, also guarded against unduly strenuous exercise, aiming for a rating of perceived exertion of 12–14 on the Borg scale as recommended by Royal College of Obstetricians and Gynaecologists guidelines.[10] The larger increase in heart

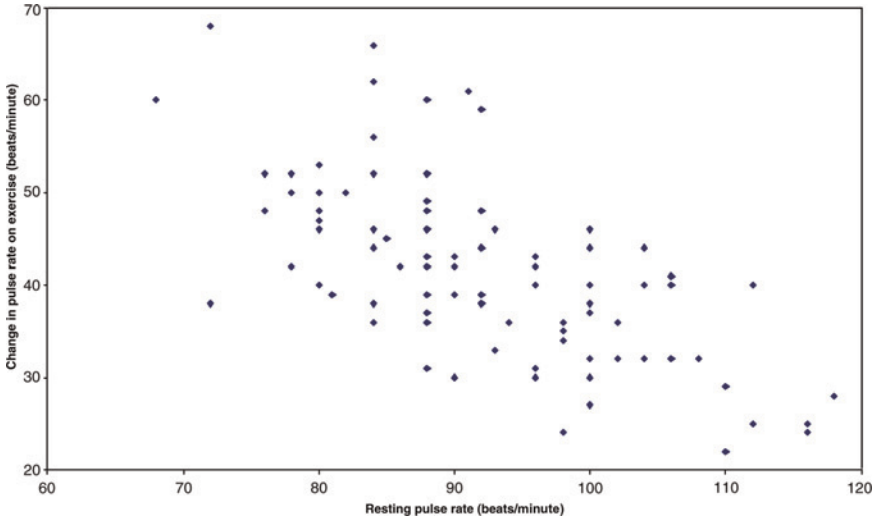

Figure 3 **Graph of change in pulse rate on exercise against resting pulse rate**

rate on exertion seen in women with lower resting heart rates may reflect a greater intensity of exercise performed by those who were fitter, hence higher vagal tone at rest. Since women walked at their own pace, those with a higher level of fitness are likely to have walked faster. However, we did not measure the speed so cannot confirm this.

This study demonstrates that a simple exercise protocol, comprising a walk at normal pace and climbing two flights of stairs, represents an appropriate moderate cardiovascular challenge in most pregnant women. This protocol achieved the target of 60–80% maximum predicted heart rate in most women. Only two women had a heart rate rise to greater than 80% maximum predicted heart rate and these did not exceed 85% so the protocol does not represent an excessive amount of exercise. For women who have a high level of athletic training, the protocol may achieve less than 60% maximum predicted heart rate. It is unlikely that such women, for whom the test is 'too easy', have significant disease, but a simple extension of the exercise to another flight of stairs could easily provide sufficient challenge to raise the heart rate to the required level.

The advantage of this protocol is that it is simple, widely applicable in most clinic settings, and does not require equipment other than a pulse oximeter. It therefore provides a rapid, readily available screening test. However, further studies are required to define the performance of this test in women with known cardiovascular or respiratory disease and therefore the ability of the test to differentiate between physiological and pathological shortness of breath.

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