Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
Effects of a University Fitness Programme on Cardiorespiratory Fitness, Muscle Strength and Endurance, Body Composition, and Flexibility of Previously Sedentary Females.

A thesis presented in partial fulfillment of the requirements for the degree of Master of Science in Physiology at Massey University.

Christine Ann Scott
1995
Abstract

Thirty-eight healthy females between the ages of 20 and 49 that had not undertaken any training for at least two months prior to the experiment were studied to determine the effects of six weeks of a combined circuit weight training and aerobic programme on estimated maximal oxygen consumption (\(\dot{V}O_2\text{max}\)), muscular strength, body composition and flexibility. Nineteen of the volunteers participated in the exercise programme while the remaining nineteen served as control subjects. Prior to the training programme each subject took part in two testing sessions. Further testing was conducted after 3 weeks (1 testing session) and at the conclusion of the training programme (two testing sessions). Estimated \(\dot{V}O_2\text{max}\) was determined from heart rate and oxygen uptake during a submaximal test using a cycle ergometer. Muscular strength was determined from an estimated one repetition maximum and maximum number of repetitions for a set weight for the bench press, leg press, leg extension and abdominal crunches. Body composition was evaluated from the sum of the triceps, subscapular, suprailiac, abdomen, thigh and calf skinfolds. Flexibility was evaluated for the hamstring muscle group (using the sit and reach test), gastrocnemius and soleus muscles and shoulders. The training programme consisted of three 25-40 minute sessions a week on The Massey University Recreation Centre Supercircuit. The supercircuit consisted of thirty-six 40-second exercises which include 11 aerobic exercises and a variety of weight training and calisthenic exercises. Data was analysed using regression analysis and one factor ANOVA. There was no significant increase in the mean estimated \(\dot{V}O_2\text{max}\) following the training period. The estimated 1RM increased by 40% and the maximum number of repetitions for a set weight increased by 100% for the bench press. The estimated 1RM increased by 16% for the leg press and the maximum number of repetitions for a set weight increased by 52% for the leg extension. The number of abdominal crunches completed in one minute increased significantly. There was no significant change in body mass or the sum of the skinfolds. There was a significant increase in the flexibility of the hamstring muscle group but not of the gastrocnemius and soleus muscles and shoulders. Over the six weeks of the study period subjects felt they had significantly improved in stamina, muscle tone, strength, flexibility and general well being and had made small improvements in body shape. It was concluded that the supercircuit at the Massey University Recreation Centre is an effective means of improving muscular strength in sedentary females but it may not be as effective at improving cardiorespiratory fitness and body composition as some other forms of exercise.
Acknowledgements

I wish to thank my supervisors Dr Rodger Pack, Dr Heather Simpson and Dr Hugh Morton for their help in preparing this thesis.

Special thanks are also given to Chris Collins and the rest of the staff at the Massey University Recreation Centre and to Neil Ward for helping me transport equipment to and from the Physiology Dept and setting the equipment up.

I would also like to thank my husband Barry and my children Sara, Byron and Lori, for the support they have given me.
Table of Contents

Abstract ............................................................... ii
Acknowledgements ...................................................... iii
Table of Contents ..................................................... iv
List of Tables .......................................................... vii
List of Figures .......................................................... viii
List of Appendices ..................................................... xi
List of Abbreviations .................................................... xiii

1. Introduction ................................................................... 1
   1.1. Physical Fitness ...................................................... 1
       1.1.1. Programmes for Improving Physical Fitness .......... 3
               1.1.1.1. Aerobic Training Programmes .................. 3
               1.1.1.2. Resistance Training Programmes .............. 4
               1.1.1.3. Physical Fitness Programmes for Improving
                          Body Composition ................................ 6
       1.1.2. Circuit Weight Training as a means of Improving Physical
              Fitness ......................................................... 7
               1.1.2.1. Defining Circuit Weight Training .......... 7
               1.1.2.2. The Effectiveness of Circuit Weight Training
                          for Improving Strength ................................ 8
               1.1.2.3. The Effectiveness of Circuit Training for
                          Improving Cardiorespiratory Fitness .......... 10
               1.1.2.4. Problems of Testing for Cardiorespiratory
                          Fitness ....................................................... 13
               1.1.2.5. The Effectiveness of Circuit Training and Aerobic
                          Circuit Weight Training for Improving Body
                          Composition .............................................. 14
       1.1.3. The Physiological Basis of Circuit Weight Training .... 15
               1.1.3.1. The Interaction of Strength and Endurance
                          Training .................................................... 15
               1.1.3.2. Reasons for Small Improvements in VO2max with
                          Circuit Weight Training ................................ 16
       1.1.4. Summary ......................................................... 20
   1.2. The Present Study ................................................... 20
2. Methods ................................................................................................. 21
  2.1. Subjects .............................................................................................. 21
  2.2. Experimental Design .......................................................................... 21
  2.3. Supercircuit Training .......................................................................... 21
  2.4. Fitness Testing .................................................................................... 23
    2.4.1. Body Composition. ...................................................................... 23
    2.4.1.1. Height and Body Mass ....................................................... 23
    2.4.1.2. Skinfolds ............................................................................. 23
    2.4.2. Flexibility and Strength Measures ........................................... 24
    2.4.2.1. Flexibility of the Hamstring Muscle Group ....................... 24
    2.4.2.2. Flexibility of the Gastrocnemius and Soleus Muscles ...... 24
    2.4.2.3. Flexibility of the Shoulders ............................................. 24
    2.4.2.4. Abdominal Muscle Strength/Endurance .............................. 24
    2.4.2.5. Upper and Lower Body Strength ....................................... 25
    2.4.3. Cardiorespiratory Fitness .......................................................... 26
    2.4.3.1. Cycle Ergometer Test ....................................................... 26
    2.4.4. Statistical Analysis ...................................................................... 27

3. Results .................................................................................................. 28
       Training .............................................................................................. 28
  3.2. Characteristics of the Supercircuit and Control Groups Prior to
       Supercircuit Training ........................................................................... 28
  3.3. A Comparison of the Supercircuit and Control Groups over the Six
       Weeks of the Supercircuit Training Programme .................................. 29
    3.3.1. Body Composition ....................................................................... 29
    3.3.2. Blood Pressure and Heart Rate Prior to Fitness Testing ........... 29
    3.3.3 Flexibility ...................................................................................... 30
    3.3.4. Muscle Strength and Endurance ............................................... 31
      3.3.4.1. Upper Body Strength/Endurance .................................... 31
      3.3.4.2. Lower Body Strength/Endurance ................................... 32
      3.3.4.3. Abdominal Strength/Endurance ..................................... 32
    3.3.5. Cardiorespiratory Fitness ........................................................... 33
      3.3.5.1. Heart Rate and Oxygen Uptake ..................................... 33
      3.3.5.2. Estimated VO_{2max} ....................................................... 33
      3.3.5.3. Rating of Perceived Exertion ......................................... 34
3.3.5.4. Rate of Decline in Heart Rate after the Completion of the Final Work Load on the Cycle

Ergometer ......................................................... 34

3.3.6. Questionnaires ............................................. 35

3.3.6.1. Changes in Perceived Levels of Fitness .......... 35

3.3.6.2. Perceived Changes in Levels of Fitness .......... 35

4. Discussion .......................................................... 37


4.2. Characteristics of the Supercircuit and Control Groups Prior to Supercircuit Training ............................................. 38

4.3. A Comparison of the Supercircuit and Control Groups over the Six Weeks of the Supercircuit Training Programme .... 38

4.3.1. Body Composition ........................................... 38

4.3.2. Blood Pressure ............................................... 40

4.3.3. Flexibility ..................................................... 40

4.3.4. Muscle Strength and Endurance ................................ 41

4.3.5. Cardiorespiratory Fitness .................................. 43

4.3.5.1. The Effectiveness of the Supercircuit Programme for Improving Cardiorespiratory Fitness .......... 43

4.3.5.2. Problems of Demonstrating an Improvement in Estimated VO2max .................................................. 45

4.3.5.2.1. Oxygen Uptake While Training .................. 45

4.3.5.2.2. Testing Procedure .................................. 46

4.3.5.2.3. Duration of the Exercise Programme ........ 48

4.3.5.2.4. Number of subjects ................................ 48

4.3.5.2.5. Mode of testing .................................... 49

4.3.6. Perception of Fitness Levels ................................ 49

4.4. Summary ............................................................ 50

5. Conclusion .................................................................. 51

6. References .................................................................. 53

Appendices
List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Facing Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Review of Changes in Strength with Circuit Weight Training and Aerobic Circuit Weight Training.</td>
<td>8</td>
</tr>
<tr>
<td>2.</td>
<td>Review of Changes in VO2max with Circuit Weight Training.</td>
<td>10</td>
</tr>
<tr>
<td>3.</td>
<td>Review of Changes in VO2max with Aerobic Circuit Weight Training.</td>
<td>12</td>
</tr>
<tr>
<td>4.</td>
<td>Changes in Body Composition with Circuit Weight Training and Aerobic Circuit Weight Training.</td>
<td>14</td>
</tr>
<tr>
<td>5.</td>
<td>Variations in the Relationship between %VO2max, %HRmax and %HRR during Circuit Weight Training and Treadmill Running.</td>
<td>17</td>
</tr>
<tr>
<td>6.</td>
<td>Mean Heart Rate during One Exercise Session of each Subject from the 1994 Group while Participating in the Supercircuit Programme.</td>
<td>22</td>
</tr>
<tr>
<td>7.</td>
<td>Method of Estimating a One Repetition Maximum from the Maximum Load which can be Lifted Less than Ten Times.</td>
<td>25</td>
</tr>
<tr>
<td>9.</td>
<td>A Comparison of the Characteristics of the Control and Exercise Group using ANOVA.</td>
<td>28</td>
</tr>
<tr>
<td>10.</td>
<td>Changes in the Mean Response to a Questionnaire on Perceived Levels of Fitness of the Supercircuit and Control Groups in 1994.</td>
<td>35</td>
</tr>
</tbody>
</table>
# List of Figures

<table>
<thead>
<tr>
<th>Figure:</th>
<th>Facing Page:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Layout of the Circuits Room at The Massey University Recreation Centre</td>
<td>22</td>
</tr>
<tr>
<td>2. Body Mass Measurements of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>29</td>
</tr>
<tr>
<td>3. Sum of the Suprailiac and Abdominal Skinfolds of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>29</td>
</tr>
<tr>
<td>4. Sum of Triceps, Subscapular, Suprailiac, Abdominal, Thigh, and Calf Skinfolds of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>29</td>
</tr>
<tr>
<td>5. Systolic Blood Pressure of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>29</td>
</tr>
<tr>
<td>6. Diastolic Blood Pressure of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>29</td>
</tr>
<tr>
<td>7. Pre-exercise Heart Rate of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>29</td>
</tr>
<tr>
<td>8. Right + Left Hamstring Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>30</td>
</tr>
<tr>
<td>9. Right Hamstring Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>30</td>
</tr>
<tr>
<td>10. Left Hamstring Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>30</td>
</tr>
<tr>
<td>11. Right Gastrocnemius Muscle Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>30</td>
</tr>
<tr>
<td>12. Left Gastrocnemius Muscle Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks</td>
<td>30</td>
</tr>
<tr>
<td>13. Right Soleus Muscle Flexibility of the Supercircuit and Control Groups at Zero,</td>
<td>30</td>
</tr>
</tbody>
</table>
Three, and Six Weeks

14. Left Soleus Muscle Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

15. Right Shoulder Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

16. Left Shoulder Flexibility of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

17. Bench Press Estimated 1RM of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

18. Maximum Number of Bench Press Repetitions at a Set Load of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

19. Leg Press Estimated 1RM of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

20. Maximum Number of Leg Extension Repetitions at a Set Load of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

21. Number of Repetitions in One Minute of Abdominal Crunches of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

22. Heart Rate at the Third Workload on the Cycle Ergometer of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

23. Oxygen Uptake during the Third Workload on the Cycle Ergometer of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

24. Estimated VO$_2$max Calculated from Oxygen Consumption of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

25. Estimated VO$_2$max Calculated from External Work (watts) of the Supercircuit and Control Groups at Zero, Three, and Six Weeks

26. Rating of Perceived Exertion for the Third Workload of the Supercircuit and Control Groups at Zero, Three, and Six Weeks
27. Rate of Decline in Heart Rate after the Completion of the Third Workload of the Supercircuit Group at Zero, Three, and Six Weeks 34

28. Rate of Decline in Heart Rate after the Completion of the Third Workload of the Control Group at Zero, Three, and Six Weeks 34
List of Appendices

Appendix A

1. Physical Activity Readiness Questionnaire (PAR-Q)
2. Questionnaire: "Perceived Level of Fitness"
3. Questionnaire: "Perceived Changes in Fitness Levels"
4. Primary Training Effect of Each Exercise in the Massey University Recreation Centre Supercircuit
5. Skinfold Sites
6. Rating of Perceived Exertion

Appendix B

1. Age, Height, Body Mass, Blood Pressure, Pre-exercise Heart Rate, and Skinfold Measurements obtained from 38 Subjects.
2. Flexibility and Strength Measures obtained from 38 Subjects.
3. Heart Rate, Perceived Exertion, and Oxygen Uptake Data obtained from 38 Subjects. During Cycle Ergometer Tests.
4. Results of the Questionnaires Completed by the 1994 Group prior to and after the Six Week Supercircuit Programme.

Appendix C

2. Summary Tables for ANOVA for the Comparison of Characteristics of the Supercircuit and Control Groups

Appendix D

Tables of Results.
1. Pre-, mid-, and post-six week Body Composition Characteristics.
2. Pre-, mid-, and post-six week, Pre-exercise Blood Pressure and Heart Rate.
3. Pre-, mid-, and post-six week Flexibility Characteristics.
4. Pre-, mid-, and post-six week Strength Characteristics.
5. Pre-, mid-, and post-six week Heart Rate at the Third Workload on the Cycle Ergometer.
6. Pre-, mid-, and post-six week Oxygen Uptake at the Third Workload on the Cycle Ergometer.
7. Pre-, mid-, and post-six week Estimated Maximum Oxygen Uptake.
8. Pre-, mid-, and post-six week Rating of Perceived Exertion on the Cycle Ergometer.
9. Pre-, mid-, and post-six week Rate of Decline in Heart Rate after the completion of the Third Workload on the Cycle Ergometer.

E. Multiple Regression Equations for Each Characteristic over Six Weeks
List of Abbreviations

CWT: circuit weight training
Load: the mass (kg) or amount of resistance against which a muscle works.
Repetition: a single complete action of an exercise from starting position to completion and back to the starting position.
1RM: One repetition maximum; the maximum load that can be lifted for one repetition only.
5RM: Five repetition maximum: the maximum load that can be lifted for five repetitions only.
5-10RM: Five - ten repetition maximum: the maximum load that can be lifted for between five and ten repetitions only.
bpm: heart rate in beats per minute
HRmax: maximum heart rate
HRR: heart rate reserve
L/min: litres per minute
ml/kg/min: millilitres/kilogram /minute
ml/kg LBW/min: millilitres/kilogram lean body weight/minute
pre-exercise HR: heart rate prior to participating in the cycle ergometer test
RMR: resting metabolic rate
RPE: rating of perceived exertion
R-hamstring: right hamstring muscle group
L-hamstring: left hamstring muscle group
R+L hamstring: right plus left hamstring muscle group
SKF-2: sum of the suprailiac and abdominal skinfolds
SKF-6: sum of the triceps, subscapular, suprailiac, abdominal, thigh and calf skinfolds
VO2max: maximal oxygen uptake
C: regression variable representing training status
T: regression variable representing time
CT: regression variable representing training status x time
Tsq: regression variable representing time squared
CTsq: regression variable representing training status x time squared
ANOVA: analysis of variance