Skin and core body temperature changes during exercise

I cycle for the school cycle team and I notice that when I exercise that I feel hotter. This links to the information that we have learnt about different energy systems and the production of heat when we breakdown ATP. The workbook highlighted the fact that heat energy is created as a by-product of ATP being converted to ADP and P. During our current topic we have been looking at “thermoregulation” and the way that the body monitors and then maintains a relatively stable (homeostatic) core body temperature. The body relies on several key processes in order to maintain a stable body temperature. These include: evaporation, radiation, conduction and convection. The cooling process is heavily reliant on evaporation. What puzzles me however is the sometimes contradictory information about skin temperature. While there is research to say that skin temperature decreases initially during exercise; the researchers put the decline down to vasoconstriction of blood flow to the skin in the initial stages rather than sweating and the evaporative cooling mechanism. There is other information, from both research and from a personal experience, which tells me that when I exercise my skin temperature increases. Roberts (1979) states; "At any given environmental and mean skin temperature, exercise brings about an increase in internal body temperature and skin blood flow."

On a personal level the warmth that I feel when I exercise both internally and on my skin are clear signs that the rate of respiration has increased and blood flow to my extremities has actually increased (contrary to Torii's view) and so in a comparative way (rest to exercise) I feel it is justifiable to expect that core and skin temperature would actually increase from rest to exercise and then decrease once exercise stops. Based on my experiences and also on the studies mentioned I would like to challenge the findings of Torii 1992, and investigate the question;

How do skin and core temperatures (°C ± 0.1°C) change while cycling for 20 minutes (± 1 minute) on a stationary cycling machine at 75 revolutions per minute (± 5 RPM) in 6 male subjects aged 16-17 years old?

Independent variable:
Measurement point on the body:
- Biceps
- Forearm
- Lower back
- Core (auditory)

Dependent variable:
- Skin temperature: measured via a hand held thermometer °C (± 0.1°C)
- Estimated core temperature: measured via an auditory thermometer °C (± 0.1°C).

Measurements will be taken at rest (0 minutes) and then every 5 minutes (± 1 minute) for 20 minutes of exercise then for 10 minutes of recovery.

Although there may be more accurate means for measuring temperature the auditory thermometer was used because it is practical for its relative accuracy, comfort, and it's relatively non-invasive ability to get recordings while someone is cycling; additionally it provides quick data via a cost effective means.

Control variables:

<table>
<thead>
<tr>
<th>What?</th>
<th>How to control?</th>
<th>Why does it need controlling?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>Ensure the person is reasonably fit.</td>
<td>We need the subject to be able to continue cycling for the duration of the experiment to get a full data set.</td>
</tr>
<tr>
<td></td>
<td>Ensure the subject is kept at the correct cycling rate ~75 RPM (± 5 RPM) on resistance level 3 of the cycling machine.</td>
<td></td>
</tr>
<tr>
<td>Allow the temperature</td>
<td>Hold the measurer steady on the skin or in the ear until a stable reading is indicated.</td>
<td>Improve the accuracy of the reading the equipment by allowing it to establish a true reading.</td>
</tr>
<tr>
<td>gauge to stabilize</td>
<td></td>
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</tr>
</tbody>
</table>

1 (M. Torii MSc, 1992)
2 (Roberts MF, 1979)
<table>
<thead>
<tr>
<th>Same measurement place on each subject for the skin measurement</th>
<th>Mark the area on the person so that the same area is used each time. In this case the position is the middle belly of the right bicep muscle.</th>
<th>Temperature in different areas of the body may read differently as blood is distributed about the body.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Note: the regions on the skin (biceps, forearm, lower back) were selected because they will be easy to measure while the subject continues to cycle. Regions on the leg will be in constant motion and this will be too difficult to use.</td>
<td></td>
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</tr>
<tr>
<td>Distance that the skin thermometer is from the person.</td>
<td>As you adjust the skin temperature machine's distance from the arm you will notice that the beam changes from a double beam (correct distance) to a single beam (far too close). Adjust the distance until the beginning of the single beam – and use this position as the measuring point.</td>
<td>The skin temperature measurer's accuracy may vary depending on how far the gun is from the subject.</td>
</tr>
<tr>
<td>Cycling technique</td>
<td>Have subjects set the seat appropriately for their height so that they can comfortably and efficiently cycle. When they are seated on the bike with their feet inserted into the pedals when the foot is at a half-way point the leg is bent at 90°; then when fully extended it is almost (not quite) straight. It needs to be comfortable but not limiting in terms of power output. Arms should be on the bars in the normal fashion.</td>
<td>This is to ensure that they all use their legs correctly and manage the intensity well; to incorporate upper body muscles as much as possible, and to minimize the risk of injury.</td>
</tr>
<tr>
<td>Clothing</td>
<td>Students are to wear the normal school PE uniform which is shorts and t-shirt.</td>
<td>The amount and type of clothing can affect the skin cooling process significantly, so the materials that the clothing is made from should be consistent and the wicking process and skin coverage will be the same.</td>
</tr>
<tr>
<td>Subjects</td>
<td>Select all male subjects who are of the same age (16-17 years), size and approximate level of fitness. I will select males from our class (Year 13) and from subjects who play sport at a premier level.</td>
<td>This will ensure that the type of data being collected is drawn from similar types of subject and that the variables of fitness or body mass are eliminated as much as possible from influencing the data.</td>
</tr>
<tr>
<td>Warm down procedure</td>
<td>Have subjects sit on a bench near the bike.</td>
<td>To ensure that no further exercise is done after the 20 minute cycle.</td>
</tr>
</tbody>
</table>
Safety and Confidentiality:

Issues with this experiment to be concerned about include:

- Care with the laser beam emitted from the IR skin thermometer. Care will be taken to ensure that is not pointed toward the eyes of any subject.
- Hygiene practices with the auditory thermometer: each subject will be asked to ensure that their ears are cleaned before the experiment. During the experiment each student will be allocated their own cover/ cap which will be labeled for identification purposes. This will ensure that the same cap is not used on different subjects. Additionally I should have on gloves for further protection.
- PAR-Q: a basic/ modified PAR-Q (refer to page 4) will be completed by each participant to ensure that they are going to be appropriate for this experiment and that no health issues exist that we should be worried about.
- Wearing of shoes: Shoes will ensure that they are comfortable and can continue for the time needed without getting blisters and also there may be issues of hygiene if they wear bare feet.
- Subjects will be informed that their data will be kept confidential and that no one will know which data refers to which subject.

Confounding variables (variables we can not control): these will be checked and considered

- atmospheric temperature/ humidity on the day -- all testing will try to be collected on similar days if more than 1 day is needed.
- Attitude/ motivation: subjects are volunteers and so hopefully this will ensure that they are going to do their best for me.
- diet/ hydration – subjects will be asked to eat a normal breakfast/ morning tea and water will be available as needed. The testing/ experiment will be completed in the schools double period 11am to 12.30pm.
- sickness/ injury: if subjects are unwell they will not be allowed to take part.

Equipment:

- IR hand held thermometer
- Auditory thermometer
- Caps for auditory thermometer – labeled for each subject
- Marker pen to mark skin (biceps) and also label the caps
- 2 Stationary cycles
- Stop watches x 2 – to allow you to monitor 2 cyclists at once
- Pen and paper for recording data
- 6 male subjects (sports science class volunteers)

Method:

- Record the room temperature before you begin – I use the climate control device in the room to inform me what the room temperature was.
- Before the subjects cycled I had them complete the PAR-Q and ensured they understood the nature and intent of the experiment and also were aware that they can pull out at any stage. Once this was done and they were cleared to proceed I located and marked with a marker the place that they were to be tested for skin temperature. I made a circle inside which I tested/ put the beam. The region will be lower biceps (see diagram page 2).
  1. I took the skin temperature for subject 1 and 2 (my first subjects) prior to them beginning to cycle. I recorded this result as “time zero”.
  2. I used the auditory thermometer with the subjects named cap on to take 3 initial “0 minutes” readings of core temperature and recorded this.
  3. I had the first subjects set the cycle machines to fit their leg length for maximizing their leg power and comfort – see control variables for expectation/ description of this.
  4. Subject 1 then turned-on the bike and set the resistance level to 3.
  5. I started stopwatch 1 with the beginning of subject 1 cycling for their 20 minutes.
  6. Subject 2 waited 30 seconds before they set the machine to level 3
  7. Stopwatch 2 was started when subject 2 began to cycle for their 20 minutes.
  8. I had the cyclists raise and maintain their rate of cycling to approximately 75 RPM by monitoring the screen for each of the bikes.
  9. I recorded skin (1 repeat) and core (3 repeats) temperatures every 5 minutes (±1 minute) until they had done 20 minutes of cycling.
  10. As each one finished and the last readings were taken they came off the bike and sat down on the bench so that 2 further temperature recordings could be made (after 5 minutes then 10 minutes of recovery)
- When that was completed I thanked the subjects and then prepared the same procedure to occur for subjects 3 and 4 – starting at 1 above and working through to 10) then when they were completed the final 2 subjects were done (1 to 10).
- Due to time pressures subjects 5 and 6 were done the next day.
Physical Activity Readiness Questionnaire (PAR-Q)

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise and the completion of PAR-Q is a wise first step to take. For most people physical exercise should not pose any problem or hazard. PAR-Q has been designed to identify the small number of individuals for whom physical activity might be inappropriate, or those who should seek medical advice concerning the type of activity most suitable for them. Common sense is your best guide in answering these few questions. Please read them carefully and answer "YES" or "NO". If you are about to be examined by the clinic doctor please still complete this questionnaire.

<table>
<thead>
<tr>
<th>Question</th>
<th>YES/NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Has your doctor ever said that you have heart trouble?</td>
<td></td>
</tr>
<tr>
<td>(2) Do you frequently have pains in your chest?</td>
<td></td>
</tr>
<tr>
<td>(3) Do you often feel faint or have spells of dizziness?</td>
<td></td>
</tr>
<tr>
<td>(4) Has a doctor ever said your blood pressure was too high?</td>
<td></td>
</tr>
<tr>
<td>(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?</td>
<td></td>
</tr>
<tr>
<td>(6) Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?</td>
<td></td>
</tr>
<tr>
<td>(7) Are you taking medication that might affect your response to exercise?</td>
<td></td>
</tr>
<tr>
<td>(8) Have you been prescribed or are you taking drugs that reduce your blood pressure or reduce your heart rate?</td>
<td></td>
</tr>
</tbody>
</table>

If you have answered YES to one question or more in the PAR-Q then you should consult with your doctor BEFORE being involved in this assessment. If you have answered NO to all questions and you have answered PAR-Q accurately, you have reasonable assurance of your present suitability for involvement.

Declaration

I have understood the importance of the PAR-Q questionnaire. I understand that although every reasonable precaution will be taken to ensure complete safety during this research, 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 research, and understand that I can withdraw at any time. I agree to participate in the research, the nature of which has been clearly explained to me.

Signed: ____________________________
Date: ____________________________

Print name: ____________________________
D.O.B: ____________________________

Adapted from: http://www.fbpt.co.uk/PARQ.pdf
Table 1: Skin Temperatures (°C ± 0.1°C) during 20 minutes of cycling on a stationary cycle at 75 revolutions per minute (± 5 revolutions per minute) and 10 minutes of recovery in 6 Year 13 subjects.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Temperature Measurement Point (refer to key)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.2</td>
<td>30.9</td>
<td>29.5</td>
<td>28.7</td>
<td>27.9</td>
<td>27.9</td>
<td>28.4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>31.3</td>
<td>31.2</td>
<td>30.2</td>
<td>29.8</td>
<td>29.4</td>
<td>29.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>32.0</td>
<td>31.2</td>
<td>30.0</td>
<td>28.7</td>
<td>28.4</td>
<td>29.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>31.4</td>
<td>30.0</td>
<td>31.5</td>
<td>31.8</td>
<td>29.8</td>
<td>29.3</td>
<td>30.5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>31.4</td>
<td>30.2</td>
<td>27.6</td>
<td>26.4</td>
<td>27.2</td>
<td>27.4</td>
<td>27.6</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>30.1</td>
<td>29.4</td>
<td>30.3</td>
<td>29.8</td>
<td>29.5</td>
<td>30.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>31.2</td>
<td>30.5</td>
<td>29.9</td>
<td>29.3</td>
<td>28.6</td>
<td>29.0</td>
<td>29.5</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Core Temperatures (°C ± 0.1°C) during 20 minutes of cycling on a stationary cycle at 75 revolutions per minute (± 5 revolutions per minute) and 10 minutes of recovery in 6 Year 13 subjects.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Temperature Measurement Point (refer to key)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36.0</td>
<td>36.4</td>
<td>36.4</td>
<td>36.7</td>
<td>37.1</td>
<td>37.2</td>
<td>37.3</td>
<td>36.9</td>
</tr>
<tr>
<td>2</td>
<td>36.2</td>
<td>36.3</td>
<td>36.3</td>
<td>36.4</td>
<td>36.3</td>
<td>36.3</td>
<td>36.3</td>
<td>36.3</td>
</tr>
<tr>
<td>3</td>
<td>37.0</td>
<td>36.5</td>
<td>37.1</td>
<td>37.0</td>
<td>36.9</td>
<td>36.9</td>
<td>36.9</td>
<td>36.9</td>
</tr>
<tr>
<td>4</td>
<td>36.2</td>
<td>36.3</td>
<td>36.3</td>
<td>36.3</td>
<td>36.3</td>
<td>36.3</td>
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<tr>
<td>5</td>
<td>37.4</td>
<td>37.4</td>
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<td>6</td>
<td>36.3</td>
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<td>36.3</td>
<td>36.3</td>
<td>36.3</td>
<td>36.3</td>
</tr>
<tr>
<td>Mean</td>
<td>36.5</td>
<td>36.6</td>
<td>36.8</td>
<td>37.0</td>
<td>37.0</td>
<td>37.0</td>
<td>37.0</td>
<td>37.0</td>
</tr>
</tbody>
</table>

Means and standard deviations were calculated by using the data for all subjects for a particular measurement point. I have colour coded the zones either clear or orange to show how the data was blocked for these calculations. The means and respective standard deviations are then illustrated in the graphs on the next page. Standard deviation is indicated as ± 1 standard deviation.
Graph 1: Average Skin Temperature (°C ± std dev) during 20 minutes of cycling and 10 minutes of recovery on a stationary bike set to level 3 in 6 Year 13 subjects.

Graph 2: Average Core Body Temperature (°C ± std dev) during 20 minutes of cycling on a stationary bike and 10 minutes recovery in 6 Year 13 subjects.
General observations:
- Testing done on differing days.
- Temperature on Day 1 testing (subjects 1+2) was 18°C; Temperature on Day 2 testing (subject 5-6) was 19°C.
- Humidity was similar on both days.
- All subjects showed signs of sweating as the exercise progressed.

Subject 1
Regularly moved shoulder, not maintaining stance.
Had earphones in.

Subject 2
Straighter back than subject 1.
Low upper body movement - like a cyclist.
Headphones worn.

Subject 3
Didn’t maintain one cycling position throughout, however, had technique when in a certain position E.g.
Low down, or straight back.
Earphones.
Ensured measurer was aware of time.

Subject 4
Often erratic cycling cadence - not between 70-80 RPM needed watching.

Subject 5
Small ears, hard for thermometer reading.
Earphones.

Subject 6
Good form on the bike.

T-Test:
From the graphs you can see that for both the skin and core temperatures that they gradually decrease or increase from 0 minutes to 20 minutes. In order to see if these changes (0 minutes to 20 minutes) are actually different (significantly) statistically and not explainable just as normal temperature fluctuations I carried out a t-test. When you look at the graphs of mean data with standard deviations although they appear different – the comparatively large standard deviations give the impression that there is significant overlap. This is where using the t-test allows for these components and in the end it shows that the temperature changes between resting (0 minutes) and 20 minutes of exercise are very statistically significant (skin temperature p=0.0043) and extremely statistically significant (core temperature p=0.0001)

As a check on this t-test result I used Excel to carry out a t-test also (see below). The data for time 0 and 20 minutes was put into the t-test formula; a 2 tails test was then selected (2) and then a paired test was selected (1) as the subjects are the same in both conditions. The p-value came out at 0.004 which is smaller than 0.01 and indicates that the data is extremely significantly different.

A 1: Relevant qualitative data which will assist with the evaluation.
A 4: T-Test data is correctly interpreted and supports a valid conclusion.
A 2: Large standard deviation stated but not explained.
A 2 (processing) and A4 (interpretation of data).
C 2: Repeated test.

(http://www.graphpad.com/quickcalc/ttest?)
As a check on this impressive t-test result I used Excel to carry out a t-test also (see below). The data was first averaged for each subject for each time slot. This was done because there were 3 raw values per subject for each time slot. The average data was then put into the t-test formula; a 2 tails test was then selected (2) and then a paired test was selected (1) as the subjects are the same in both conditions. The p-value came out at 0.0009 which is smaller than 0.01 and indicates that the data is extremely significantly different.
Investigation 10 (annotated)

Conclusion/Evaluation:
This investigation attempted to uncover the phenomenon of how skin temperature changes as they exercise. It was expected that skin temperature would increase (hands, face), as this is what was experienced during personal exercise sessions. Information also suggested that exercise brings about an increase in skin blood flow. Later research investigated skin temperature decreases, which were found initially during exercise. It was suggested this was due to vasconstriction of blood flow to the skin in the initial stages rather than sweating and the evaporative cooling mechanism. In order to investigate this the following research question was proposed:

How does a person's skin and core temperature (°C ± 0.1°C) change while cycling for 20 minutes ± 1 minute on a stationary cycling machine at 75 revolutions a minute (± 5 RPM)?

Quite unexpectedly the results, which I have obtained, support those from Torii et al (1992) in terms of the changes of skin temperature. That is, that as we exercise our skin temperature begins to decrease. In this investigation core temperature was also monitored and this showed a small but significant increase over the exercise time. The mechanisms involved, which have caused these changes, were beyond the scope of this investigation, but I will attempt to explain these from my observations.

Looking at graph 1 we can see that the skin temperature starts (mean ± std dev) at 31.2°C ± 0.5°C and then steadily drops to its lowest point at 20 minutes (end of exercise) 28.6°C ± 1.1°C. The trend appears to be consistent overall as seen by the line of best fit; showing a steady decline until the end of exercise followed by a gradual raise for 10 minutes after exercise back to normal resting levels. The standard deviations appear to be relatively high (range 0.5 to 1.8°C). This is due to the “between subject” variation in skin temperature. I put the data for skin temperature into the paired t-test using the online calculator to compare time 0 with 20 minutes of exercise in order to see whether resting temperatures differed from the end of exercise figures.

Based on the result the differences are considered to be very significantly different (p value = 0.0043) i.e. the resting skin temperature is significantly higher than skin temperature after 20 minutes of exercise. The logical reason for the difference is that exercise has triggered cooling processes at the skin. Although this is only for six subjects the results and their consistency are generally quite remarkable. Unlike Torii however, I cannot discount the effect of evaporative processes on the skin as all subjects showed clear signs of sweating.

Vasoconstriction however, could also be a reason for these temperature drops as we were only testing on the arm (biceps), which was a region of the body that would have been hardly used. Sources suggest that blood is redirected from tissues that aren’t needed by vasoconstriction, to working muscle tissues, as is the case in this situation.

In contrast, the core temperatures steadily increased (graph 2) until 20 minutes of exercise and then gradually decreased. Later research investigated skin temperature decreases, which were found initially during exercise. The measured core temperature is far warmer and more consistent than the skin (core range 36.5 to 37.0°C versus skin 31.2 to 28.6°C). This implying the body controls the internal temperature more than the external one, explaining why there is more variation of the skin temperature before, during and after exercise. This supports the literature? that the skin’s surface is used as a way of releasing heat to maintain the body core temperature.

The core temperatures standard deviations vary for each time section anywhere from 0.3 to 0.5°C. This is consistent in the times indicating that the differences within and between subjects was consistent. We can also be seen when looking at table 1 and 2. This indicates that the measuring of temperatures was consistent and reliable. When the data was entered into the t-test calculator to compare “time 0 minutes and 20 minutes” it indicated that the differences were extremely statistically significant (p=0.0001). So although the differences between core temperatures before exercise (36.5°C) and after exercise (37.0°C) are small, the temperature differences are significantly different due to exercise.

An explanation for these changes is that as the subject begins to exercise, their heart and breathing rate increases in order to increase the cardiac output of oxygenated blood to fuel the skeletal muscles generating the relevant movements (cycling). This increases the blood volume in the working skeletal muscles, found below the skin. The increased cellular activity (production and usage of ATP, friction of moving body parts) has the by-product of heat, therefore causing the core temperature to increase (as we see in the investigation).

Homeostatic processes control this temperature increase, by removing excess heat with blood movement to the skin surface, and enabling heat loss by the evaporation of sweat from the skin. This means the body maintains its temperature internally. Sweating creates a moist skin surface as the body exercises. The
process of the sweat reacting evaporating causes the surface temperature to reduce\textsuperscript{9}. Therefore explaining why the skin temperature decreased until the exercise was over. At the end of the exercise, when the sweat process returns to normal, the skin temperature begins to increase again to its starting point. The body is no longer creating heat at the same rate as a by-product of ATP production; therefore the production of sweat reduces.

While the average figures found in this investigation reflected the researched trends\textsuperscript{10}, there are individual cases of the data not following those trends. Subject 4’s skin temperatures increased gradually from 30.8 to 31.8°C (time 0 to 15 minutes). A suggested explanation for this is explained further below. It isn’t until we look at data for all subjects together that we are able to see an overall trend as stated earlier. Other than this the data appears to be remarkably consistent for subjects core and skin temperatures across the time frame measured.

Limitations and improvements:

Due to time constraints the testing was completed over 2 days. This resulted in the room temperature varying for different groups of subjects. When we look at the raw data to see if this made a significant impact, the data across both days for the subjects (subjects 1-4 versus 5-6) all appears to be extremely similar. This shows that the differences in atmospheric temperatures on the day were negligible. To eliminate any issue with changeable temperatures across multiple days the experiment could be carried out in a room with an adjustable air conditioning unit. By setting the room temperature an hour before hand the room could be stabilized to the level required.

The variations in cycling technique adopted by subjects along with subjects having headphones/ music playing again appear to have had little if any influence on core and skin temperatures as indicated by the small standard deviations (skin: 0.5 to 1.8°C; core: 0.3 to 0.5°C). I believe that the cycling machine minimized the impact of this variable on the results. It was easy to adjust the seat position in order to maximize the leg power/ output. The main variation came from the maintenance of the set cadence. Interestingly, subject 4 was the only one who struggled to maintain the cycling speed (75 RPM) to the correct levels; they needed regular reminders to adjust/ lift their speed. Based on my knowledge of this subject, it was due to inattention rather than a lack of fitness. It is interesting to note that their skin temperature was the one identified in the data above to have gone against the trend and increased up to 15 minutes into the experiment. Additionally, when you look at the core data for this subject it sits below the overall average for the majority of the recorded time slots (range of the difference = 0 to 0.4°C), indicating that they are not working as hard as the other subjects.

The core and skin data results obtained for this subject indicates the importance of maintaining a consistent level of exercise intensity to ensure that the results are valid. In future this variable needs to be emphasized with the subjects and closely monitored by the experimenter. It could easily be monitored and recorded every 5 minutes along with the temperature recordings being done.

The measurement location on the skin (biceps) was a variable that was well controlled, with it being explicitly marked by a small pen mark. This was one the most consistent variables, and was maintained throughout the experiment. The range of the dependent variables for skin temperature measurement was only 1 per time slot. This should have been 3 times per time slot (same as core). This would allow for a check on the accuracy of the measuring tool and measurer. Additionally, if done again it would be beneficial to have recorded temperatures from different regions of the body such as the quadriceps area so that skin from the regions where working muscle could be analyzed. This would be a good comparison and may result in differences due to vasoconstriction and vasodilation to different skin areas.

The distance of the thermometer from the skin was easy to manage as each time the skin temperature was taken two red laser dots could be seen on the skin. By moving the device closer or further away the dots would merge at a set distance. This made the range of variability for this feature negligible.

The use of both the infrared skin thermometer and auditory thermometer was suitable for the skin and core measurements. Both were very quick at detecting the temperature and had a high degree of accuracy (± 0.1°C). The number of subjects I used was too small and needed to be increased in order for more reliable general trends to be observed. We had only 6 subjects – 30 to 50 subjects all of a similar fitness level would have been better. With such a small number of subjects, if one or more subjects underperform as in subject 4’s case, this can have a large affect on the data.

The clothing used by the subjects was all the same as indicated in the control variables (school PE kit). The materials allowed for equal wicking of sweat for all subjects. Additionally each subject wore sports shoes as requested and this assisted with preventing blisters/ pain and so technique could be maintained throughout.

If I were to repeat this investigation again I would look to raise the RPM to 85 RPM at level 3 on the bike as requested and this assisted with preventing blisters/ pain and so technique could be maintained throughout. It was easy to adjust the seat position in order to maximize the leg power/ output. The main variation came from the maintenance of the set cadence. Interestingly, subject 4 was the only one who struggled to maintain the cycling speed (75 RPM) to the correct levels; they needed regular reminders to adjust/ lift their speed. Based on my knowledge of this subject, it was due to inattention rather than a lack of fitness. It is interesting to note that their skin temperature was the one identified in the data above to have gone against the trend and increased up to 15 minutes into the experiment. Additionally, when you look at the core data for this subject it sits below the overall average for the majority of the recorded time slots (range of the difference = 0 to 0.4°C), indicating that they are not working as hard as the other subjects.

The core and skin data results obtained for this subject indicates the importance of maintaining a consistent level of exercise intensity to ensure that the results are valid. In future this variable needs to be emphasized with the subjects and closely monitored by the experimenter. It could easily be monitored and recorded every 5 minutes along with the temperature recordings being done. The measurement location on the skin (biceps) was a variable that was well controlled, with it being explicitly marked by a small pen mark. This was one the most consistent variables, and was maintained throughout the experiment. The range of the dependent variables for skin temperature measurement was only 1 per time slot. This should have been 3 times per time slot (same as core). This would allow for a check on the accuracy of the measuring tool and measurer. Additionally, if done again it would be beneficial to have recorded temperatures from different regions of the body such as the quadriceps area so that skin from the regions where working muscle could be analyzed. This would be a good comparison and may result in differences due to vasoconstriction and vasodilation to different skin areas.

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The clothing used by the subjects was all the same as indicated in the control variables (school PE kit). The materials allowed for equal wicking of sweat for all subjects. Additionally each subject wore sports shoes as requested and this assisted with preventing blisters/ pain and so technique could be maintained throughout. If I were to repeat this investigation again I would look to raise the RPM to 85 RPM at level 3 on the bike as the range used for the subjects that I had was a little too easy. This would ensure that the subjects are

\textsuperscript{9} (Sproule, 2012)

\textsuperscript{10} (M. Toni MSc, 1992)
working their body systems hard. Alternatively, monitoring heart rates would perhaps have given a more equal loading across subjects, having subjects work at 70-85% max HR (Max HR=220-age). Using the heart rate measuring tool, which is on the bikes, could do this.

Alternatively, this investigation and its aim could be carried out using a different mode of exercise, such as rowing. Rowing would work the whole body, and this would provide data from working regions as previously mentioned. This together with more skin areas being monitored (legs, arms, body) would give more clarity to the findings. It would be harder to measure with rowing however, as the subject would be constantly moving.

Having said this, it is important to note that the current investigation (using cycling) does show that both skin and core temperatures change significantly, and inversely from rest to 20 minutes of exercise.

Bibliography

1; 5; 10 M. Torii MSc, M. Y. (1992). From http://bjsm.bmj.com/content/26/1/29