Chapter 5

The effect of deceptive information about receiving cooling on pacing pattern during a 20-km cycling time trial in the heat

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ABSTRACT

Purpose
To investigate the effect of deceptive information about receiving cooling during exercise on pacing pattern during a 20-km cycling time trial in the heat.

Methods
16 Trained male participants performed three 20-km cycling time trials in 30.5 ± 0.1°C with 45 ± 3% relative humidity. The first two time trials were with (WIND) or without (CONTROL) 4 m·s⁻¹ convective cooling from km 7-13. In the third time trial, participants performed one of two trials in which they were deceived about receiving convective cooling during the trial (FALSE-NEG: expectation = no cooling, reality = cooling; FALSE-POS: expectation = cooling, reality = no cooling).

Results
Power output was lower during the entire time trial in CONTROL than in WIND (239 vs. 251 W; P=0.02). In FALSE-NEG, the pacing pattern prior to convective cooling was similar to CONTROL and during the cooling it was similar to WIND. After the cooling, no differences in pacing pattern were found between conditions. In FALSE-POS, no differences in pacing pattern were observed despite higher skin temperature, thermal sensation and thermal comfort.

Conclusion
Deceiving participants about the occurrence of convective cooling during self-paced exercise alters the pacing pattern of a 20-km cycling time trial in the heat. This shows the importance of expectations regarding thermal load in self-paced exercise.
INTRODUCTION

During self-paced exercise the human body functions as a complex system in which both anticipation and feedback are important for the regulation of exercise intensity (Tucker and Noakes 2009; Noakes et al. 2004, 2005; St Clair Gibson and Noakes 2004; Tucker 2009). The anticipatory component is reflected by the presence of a template of an initial power output (PO) and an acceptable rate of increase in the RPE during exercise. This so-called RPE template is a theoretical construct based on expected exercise duration, previous experience, and physiological (e.g. skin temperature, core temperature) and psychological (e.g. motivation level) inputs before the start of exercise (Tucker 2009). It describes an acceptable rate of increase in RPE during exercise that allows successful completion of the event while avoiding surpassing physiological limits. The feedback component includes integration of afferent information from different physiological systems (e.g. core and skin temperature, heart rate, and muscle glycogen content) during exercise. Information from these systems is used to constitute a conscious RPE that is matched with the RPE template. If the conscious RPE is different from the RPE template, the recruitment of skeletal muscle motor units, and thereby muscular PO, is adjusted (Tucker 2009).

Because psychological inputs before the start of exercise as well as afferent physiological information during exercise appear to be important for the selection and modulation of PO during self-paced exercise, not only the exercise bout itself, but also expectations about the upcoming exercise bout may influence the pacing pattern and (psycho-)physiological responses during exercise. The effect of expectations on exercise performance has been investigated in several studies. Paterson and Marino (2004) showed that time to completion of a cycling time trial was affected by manipulating the participants’ expectation of the distance of the trial. Moreover, Baden et al. (2005) supported the observation of Eston et al. (2012) that an unexpected increase in duration of exercise almost instantly increased RPE, suggesting that RPE is not only an integration of afferent physiological signals, but is also heavily dependent on (remaining) exercise...
duration. Taken together, these findings suggest that individuals exercise with a metabolic reserve (Swart et al. 2009) and that this reserve can be manipulated by deception. This notion was confirmed by Stone et al. (2012), who instructed participants to race a 40-km cycling time trial against an avatar which they believed was racing at the speed of a previous trial, but was in fact cycling at 102% of their own PO during a previous trial. This deception resulted in a shorter time to completion of the cycling time trial than in the control trial (90% confidence interval for the difference in time to completion: 2.1-10.1 s).

When self-paced exercise is conducted in the heat, generally a decrease in exercise intensity is seen over time, especially in medium to long exercise durations (> 20 min) (Abbiss et al. 2010; Peiffer and Abbiss 2011; Tucker et al. 2004). This pronounced reduction in power output with an increase of heat stress assures that the body does not reach critically high temperatures and that the exercise bout can be completed successfully (Gonzalez-Alonso et al. 1999). Cooling during exercise has been shown to be an effective method to counteract the detrimental effects of heat stress and thereby improve exercise performance (Tyler and Sunderland 2011a; Ansley et al. 2008; Tyler et al. 2010). However, it remains questionable if, and to what extent, the expectation of receiving cooling can change performance. A response based on (in)correct conscious information may be sufficient to produce a subconscious physiological effect resulting in enhanced exercise performance. Castle et al. (2012), for example, showed that during 30 min of cycling in the heat (31.5°C; 65% relative humidity), deceiving participants about the ambient conditions (reported temperature was approximately 5°C lower than actual temperature) and their own core temperature (0.30°C lower than the actual core temperature) increased mean power output by almost 10%, without differences in (thermo) physiological parameters. The increase in performance was accompanied by a lower RPE, creating a mismatch with the RPE template, resulting in a higher PO.

Although cooling during exercise in the heat has been shown to be beneficial for performance, it is still unclear to what extent this effect can be contributed to actual physiological or perceptual changes and to what extent the expectation of receiving cooling during cycling plays a role. Therefore, main goal of this study is to investigate the
effect of false information about receiving cooling on performance and pacing pattern during a 20-km cycling time trial in the heat.

**METHODS**

**Participants**

Sixteen trained, young-adult, male cyclists (De Pauw et al. 2013) participated in this study (Table 5.1). The participants were screened for known contraindications to exercise in the heat and gave their written informed consent after receiving detailed information about the study. Because of the deceptive nature of this study, participants were falsely informed that the goal of the study was to investigate the reproducibility of pacing patterns during cycling in the heat with and without convective (wind) cooling. The participants abstained from caffeine and alcohol during the 24 hours preceding an experimental trial. Moreover, they were instructed to avoid strenuous exercise the two days before a visit to the laboratory. The study was approved by the Ethical Committee of the Faculty of Human Movement Sciences of the VU University Amsterdam, The Netherlands.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>25 ± 4</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>73 ± 8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>185 ± 7</td>
</tr>
<tr>
<td>( \dot{V}O_{2\max} ) (ml·kg(^{-1})·min(^{-1}))</td>
<td>60 ± 4</td>
</tr>
<tr>
<td>( HR_{\max} ) (beats·min(^{-1}))</td>
<td>185 ± 11</td>
</tr>
<tr>
<td>Peak power output (W)</td>
<td>432 ± 39</td>
</tr>
<tr>
<td>Peak power output (W·kg(^{-1}))</td>
<td>5.9 ± 0.4</td>
</tr>
<tr>
<td>Amount of training per week (hours)</td>
<td>11 ± 3</td>
</tr>
</tbody>
</table>
Experimental design

Each participant performed an incremental exercise test to exhaustion, a familiarization 20-km cycling time trial (TT), and three experimental 20-km cycling TTs. The visits to the laboratory were scheduled at the same time of the day and at least three days apart to allow for adequate recovery. Each participant completed a 20-km TT without cooling (CONTROL) and a session with wind cooling during km 7-13 (WIND). These trials were performed in a counterbalanced fashion among participants. After the first two experimental trials, the participants were divided into two subgroups based on the peak power output (PPO) achieved during the incremental exercise test (FALSE-NEG and FALSE-POS). Both subgroups were misled about the application of wind cooling during the midportion of the subsequent TT. In FALSE-NEG, participants did not expect convective cooling whereas they did get cooling. In FALSE-POS, participants did expect convective cooling whereas they did not get it.

Incremental exercise test

During the first visit to the laboratory the participants performed an incremental exercise test to exhaustion in 22.3 ± 0.2°C with 47 ± 7% relative humidity (RH). After adjusting the cycle ergometer to the preferences of the participants, the incremental test started with a 3-min warm-up period at 100 W. After this period, the intensity increased at a rate of 25 W·min⁻¹. The test was terminated if the participant could no longer maintain a pedaling frequency of 80 revolutions per minute. During the incremental exercise test, heart rate (HR) was recorded using radio telemetry (Polar RS400, Polar Electro Oy, Kempele, Finland) and respiratory gas exchange was measured breath-by-breath using open circuit spirometry (Cosmed Quark b², Cosmed S.R.L., Rome, Italy). Before the incremental exercise test, the gas analyzer was calibrated with room air and a reference gas mixture (16% O₂ and 5% CO₂). The volume transducer was calibrated using a 3-L syringe (Cosmed S.R.L., Rome, Italy). Maximal oxygen consumption ($\dot{V}O_{2\text{max}}$) was accepted as the highest continuously recorded 30-s $\dot{V}O_{2}$. PPO corresponded to the mean power output (PO) during the last minute of the incremental exercise test. The maximum heart rate ($HR_{\text{max}}$) was determined as the average HR during the last 30 s of the test.
20-Km cycling time trials

At least two days after the incremental test, all participants performed a 20-km cycling TT to become familiar with the testing protocol and the distance of the TT. Similar to the experimental trials, participants were motivated to finish the trial as fast as possible and they were given continuous feedback about the remaining distance of the TT. During this trial, heart rate and RPE were measured. At least three days after the familiarization TT, the first of three experimental 20-km cycling TTs was performed. The temperature during these three trials was 30.5 ± 0.1°C, with 45 ± 3% RH. The experimental trials started with a 20-min passive habituation period followed by a warm-up protocol consisting of 1 min cycling at 25 W, 3 min at 45% of PPO, and 3 min at 55% of PPO. The 20-km cycling TT started 75 s after the warm-up. Participants were not allowed to ingest fluid during the TT. During the first trial, participants either did not receive any cooling (CONTROL), or received convective cooling from km 7 to 13 (WIND). The convective cooling was applied by two fans positioned in front of the participants and the wind speed amounted 4 m·s⁻¹. During the second visit to the lab, participants performed the other experimental trial (either CONTROL or WIND). After the first two experimental trials, the participants were divided into two subgroups based on the PPO achieved during the incremental exercise test. Both subgroups were deceived about the application of convective cooling during the mid-portion of the TT. They were either informed that they were not going to receive cooling, whereas they did (FALSE-NEG), or they were informed that they were going to receive cooling, whereas they did not (FALSE-POS). The incorrect information about the cooling was given to the participants before the start of the TT and was repeated during the first kilometers of the TT. Only at km 7, the participants were correctly informed about the occurrence or absence of convective cooling from km 7-13. This was accomplished by telling the participants that they were, or were not, going to receive cooling. Moreover, to avoid any discomfort or anger, it was explicitly told to the participants that the misleading about receiving cooling was part of the study. After the finish of the time trial, participants were fully debriefed about the true goal of the study and were informed why the deception was employed. Also, they were asked about their emotions at the moment of
being informed about the deception. In both FALSE-NEG and FALSE-POS, the participants reported no feelings of anger or discomfort because of the deception.

**Measurements**

After arrival at the lab, participants inserted a rectal thermistor (YSI 401, Yellow Springs Instruments, Yellow Springs, OH, USA) 10 cm beyond the anal sphincter. During the trial, rectal temperature ($T_{re}$) was recorded at 10 Hz. Skin temperature was recorded at eight locations (forehead, right scapula, left upper chest, right upper arm, left lower arm, left hand, right anterior thigh, left calf) at 0.1 Hz using iButtons (DS1922L, Maxim Integrated Products Inc., Sunnyvale, CA, USA). Mean skin temperature ($T_{sk}$) was calculated using the equation 5.1 (ISO9886 2004).

$$T_{sk} (°C) = 0.2 \cdot T_{\text{left calf}} + 0.19 \cdot T_{\text{right anterior thigh}} + 0.175 \cdot (T_{\text{right scapula}} + T_{\text{left upper chest}}) + 0.07 \cdot (T_{\text{forehead}} + T_{\text{lower arm}} + T_{\text{left upper arm}}) + 0.05 \cdot T_{\text{left hand}} \quad (equation \ 5.1)$$

HR was recorded continuously (Polar RS400, Polar Electro Oy, Kempele, Finland). PO and cadence were measured at 100 Hz. RPE was measured on a scale ranging from 6 to 20 (Borg 1982). The ratio between RPE and PO was determined for every 2-km segment to get an indication of the relationship between these two parameters. Thermal sensation (TS) and comfort (TC) were recorded every 2 km on a 9-point (-4 to 4) and 5-point scale (1-5), respectively (ISO10551 1993).

**Statistical analysis**

Statistical analysis was performed in SPSS statistical software (SPSS 20.0, SPSS Inc., Chicago, IL, USA). All participants were included in the analysis to compare CONTROL with WIND, whereas for the subgroups FALSE-NEG and FALSE-POS, only the trials (CONTROL, WIND, and FALSE-NEG/FALSE-POS) from the eight participants that were allocated to the respective subgroup were included. Experimental condition (CONTROL, WIND, FALSE-POS, FALSE-NEG) was the independent variable, whereas PO, $T_{re}$, $T_{sk}$, HR, RPE, RPE/PO, TS and TC were the dependent variables. The significance of effects of experimental condition on
The effect of deceptive information about receiving cooling on pacing during a 20-km cycling TT

the dependent variables over time was determined using two-way ANOVAs for repeated measurements (experimental condition * distance completed). This analysis was performed for the entire length of the TT and for three distinct periods during the trial separately (before convective cooling: km 0-7, convective cooling: km 7-13, and after convective cooling: km 13-20). One-way ANOVAs were used to determine the significance of effects of experimental condition on finish time and magnitude of the end spurt phenomenon. Post-hoc analyses used Bonferroni correction to adjust for multiple comparisons. Statistical significance was set at the 5% level for each analysis. Values are reported as mean ± SD.

To determine the practical (rather than the statistical) significance of the effects of wind cooling and the expectation of (not) receiving wind cooling on 20-km cycling TT performance, the effect was also expressed as 90% confidence limits. By comparing the overlap of these limits with the smallest substantial and practically meaningful change in TT performance, the chance that the observed effect was beneficial/trivial/harmful could be determined (Batterham and Hopkins 2006). For this analysis, we assume that the smallest practically meaningful change in 20-km TT finish time is 1% (Hickey et al. 1992; Jeukendrup et al. 1996).

RESULTS

Finish time and pacing pattern

Finish times and mean PO of the 20-km cycling TT is shown in Table 5.2. Finish time was shorter in WIND than in CONTROL (F=9.12, P=0.009) but no other differences between conditions were observed. Chances that the effect of wind cooling is harmful/trivial/beneficial for performance during real-life competition are 0/7/93%. For the misleading conditions, chances that the effect is harmful/trivial/beneficial are 11/25/64% for FALSE-NEG and 35/14/51% for FALSE-POS.
Table 5.2 Finish time and mean PO of the 20-km cycling TT.

<table>
<thead>
<tr>
<th>Experimental condition</th>
<th>Finish time (mm:ss)</th>
<th>Mean PO (W)</th>
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<tbody>
<tr>
<td>CONTROL</td>
<td>31:36 ± 01:44</td>
<td>239 ± 39</td>
</tr>
<tr>
<td>WIND</td>
<td>30:56 ± 01:38</td>
<td>251 ± 35</td>
</tr>
<tr>
<td>FALSE-NEG</td>
<td>31:07 ± 01:15</td>
<td>246 ± 32</td>
</tr>
<tr>
<td>FALSE-POS</td>
<td>31:20 ± 01:11</td>
<td>237 ± 26</td>
</tr>
</tbody>
</table>

In line with the shorter finish time, mean PO was higher for WIND than for CONTROL (F=6.45, P=0.02). Mean PO for FALSE-NEG and FALSE-POS were not different from CONTROL (P=0.68 for FALSE-NEG and P=1.00 for FALSE-POS) or WIND (P=0.32 for FALSE-NEG and P=0.66 for FALSE-POS). Although mean PO was higher for WIND than for CONTROL, the pacing pattern did not differ between CONTROL and WIND (interaction effect of condition and distance completed: F=0.67, P=0.52). The magnitude of the end spurt, determined as the difference in mean PO between km 20 and 19, was similar in CONTROL (39 ± 30 W) and WIND (44 ± 33 W; F=0.17, P=0.69). In the FALSE-NEG subgroup, PO was lower for FALSE-NEG than for WIND during km 0-7 (243 ± 45 W vs. 265 ± 36 W; P=0.047). When the participants realized that they were going to receive convective cooling, PO increased from 233 ± 29 W (km 7) to 256 ± 34 W (km 8; P=0.004). During the convective cooling, the mean PO in FALSE-NEG was higher than the mean PO in CONTROL (248 ± 33 W vs. 234 ± 42 W; P=0.036) and displayed a gradual decline over time. After the convective cooling period, no differences in mean PO were observed between FALSE-NEG (249 ± 39 W), CONTROL (240 ± 49 W; P=0.93), and WIND (257 ± 42 W; P=0.59). Moreover, the end-spurt in FALSE-NEG (42 ± 21 W) was not different from the end-spurt in CONTROL and WIND (F=0.12, P=0.89). In the FALSE-POS subgroup, no main effect of experimental condition (F=0.48, P=0.62) and no interaction effect between experimental condition and distance completed was observed (F=1.74, P=0.20). When participants were informed that they were not going to receive convective cooling, PO decreased (not significantly) from 246 ± 30 W (km 7) to 244 ± 28 W (km 8; P=0.32). Similarly to FALSE-NEG, the pacing pattern during the mid-portion of the TT was characterized by a gradual decline from km 8 onwards. The end-spurt in FALSE-POS (44 ± 29 W) was similar to CONTROL and WIND.
The effect of deceptive information about receiving cooling on pacing during a 20-km cycling TT (F=0.73, P=0.50). The pacing pattern during the TT (average PO for every 2-km segment of the distance completed) is shown in Figure 5.1a-c.

Figure 5.1 Pacing patterns during the 20-km cycling TT. CONTROL vs. WIND (a), FALSE-NEG subgroup (b), and FALSE-POS subgroup (c). Error bars are not displayed for clarity reasons. * Higher PO for WIND than for CONTROL (P<0.05). # Lower PO for CONTROL than for WIND and FALSE-NEG (P<0.05).
Temperature patterns

Tr at the start of the TT was not different in CONTROL (37.4 ± 0.3°C) and WIND (37.5 ± 0.2°C; F=2.72, P=0.12). Moreover, no effect of experimental condition was observed during the TT (CONTROL: 38.1 ± 0.3°C, WIND: 38.2 ± 0.3°C; F=2.13, P=0.17), and also final values were similar (CONTROL: 38.9 ± 0.4°C, WIND: 39.0 ± 0.3°C; F=1.28, P=0.28). Starting Tr in FALSE-NEG (37.3 ± 0.2°C) was similar to CONTROL and WIND (F=2.46, P=0.12). During the TT, no main effect of experimental condition was observed (FALSE-NEG: 38.1 ± 0.3°C; F=2.45, P=0.12), and also final values were not different (FALSE-NEG: 38.8 ± 0.4°C; F=1.63, P=0.23). In FALSE-POS, Tr increased from 37.3 ± 0.2°C at the start to 38.9 ± 0.4°C at the finish. No main effect of condition was found during the TT (F=0.15, P=0.86). Tr during the TT is shown in Figure 5.2a-c.

Tsk at the start of the TT was similar in CONTROL (34.8 ± 0.5°C) and WIND (35.0 ± 0.3°C; F=3.35, P=0.09), but was lower in WIND from km 8 onwards (main effect of experimental condition km 7-20: F=29.2, P<0.001). During this period, Tsk decreased from 35.7 ± 0.4°C to 34.5 ± 0.7°C in WIND (P<0.001) and increased from 35.7 ± 0.5°C to 35.9 ± 0.6°C in CONTROL (P=0.01). At the end of the TT, Tsk was similar in CONTROL (36.1 ± 0.7°C) and WIND (35.8 ± 0.6°C; F=2.82, P=0.12). In FALSE-NEG, a pronounced decrease in Tsk was observed from the moment that the convective cooling was started. The decrease in Tsk from km 7-13 was similar to WIND (F=0.63, P=0.47), showing a reduction from 35.6 ± 0.4°C to 34.2 ± 0.7°C (P<0.001). Moreover, Tsk was lower for FALSE-NEG than for CONTROL from km 7 onwards (F=17.8, P=0.008), but at the end of the TT, Tsk in FALSE-NEG was not different from CONTROL and WIND (35.7 ± 0.5°C; F=0.20, P=0.82). In FALSE-POS, the Tsk pattern during the TT was similar to CONTROL (P=1.00) and Tsk was higher than in WIND from km 8 onwards (F=71.7, P<0.001). Tsk at the finish was not different for FALSE-POS (36.2 ± 0.7°C) than for CONTROL and WIND (F=2.19, P=0.15). Tsk during the TT is shown in Figure 5.2d-f.
Figure 5.2 Rectal (a-c) and mean skin temperature (d-f) during the 20-km cycling TT. The dotted vertical lines at km 7 and 13 indicate the start and end of the convective cooling period. Error bars are not displayed for clarity reasons. * Lower $T_{sk}$ for WIND than for CONTROL ($P<0.05$). ‡ Lower $T_{sk}$ for FALSE-NEG than for CONTROL ($P<0.05$). † Lower $T_{sk}$ for WIND than for FALSE-POS ($P<0.001$).
Heart rate

Mean HR during the entire cycling TT was similar for CONTROL (170 ± 8 beats·min⁻¹) and WIND (172 ± 7 beats·min⁻¹; F=0.38, P=0.55), as was HR at the finish (CONTROL: 185 ± 9 beats·min⁻¹, WIND: 188 ± 8 beats·min⁻¹; F=1.82, P=0.20). HR during the TT in FALSE-NEG (169 ± 7 beats·min⁻¹) was not different from CONTROL and WIND (F=1.10, P=0.37). No changes in the HR pattern occurred at the moment the participants were informed that they were going to receive cooling (km 7) and also HR at the finish was similar (187 ± 12 beats·min⁻¹; F=0.96, P=0.41). Similar to FALSE-NEG, no differences in HR were observed in the FALSE-POS subgroup during the TT (170 ± 10 beats·min⁻¹; F=0.27, P=0.77), at km 7, and at the finish (184 ± 10 beats·min⁻¹; F=0.38, P=0.69).

RPE, thermal sensation, and thermal comfort

The RPE during the TT was lower for WIND (14.7 ± 1.3) than for CONTROL (15.2 ± 1.2; F=5.83, P=0.03), and also the pattern of increase was different (F=2.74, P=0.004), displaying a more linear increase in CONTROL than in WIND. In the FALSE-NEG subgroup, no main effect of experimental condition was observed (F=1.32, P=0.30), although the pattern of increase did differ between the conditions (F=2.19, P=0.004). Mean RPE during the TT in FALSE-NEG was 15.3 ± 0.9. In the FALSE-POS subgroup no difference was observed in RPE during the TT (F=1.84, P=0.20) and also the pattern of increase was not different between conditions (F=0.83, P=0.67). The mean RPE during the TT for FALSE-POS was 15.1 ± 0.4. The convective cooling resulted in a lower RPE/PO ratio in WIND than in CONTROL from km 8 onwards (F=16.3, P=0.001). In FALSE-NEG, RPE/PO was lower than CONTROL only during the convective cooling period (F=9.52, P=0.002), whereas RPE/PO was higher from km 8 onwards in FALSE-POS and CONTROL than in WIND (F=9.81, P=0.007; Figure 5.3).
The effect of deceptive information about receiving cooling on pacing during a 20-km cycling TT

Figure 5.3 RPE divided by power output during the 20-km cycling TT. The dotted vertical lines at km 7 and 13 indicate the start and end of the convective cooling period. Error bars are not displayed for clarity reasons. * Lower RPE/PO for WIND than for CONTROL (P<0.05). ** Lower RPE/PO for WIND than for CONTROL (P<0.001). † Lower RPE/PO for FALSE-NEG than for CONTROL (P<0.05). ‡ Higher RPE/PO for FALSE-POS than for WIND (P<0.001).
TS was higher during the TT for CONTROL (2.5 ± 0.1) than for WIND (1.8 ± 0.2; F=24.1, P>0.001) and this can be contributed to the decrease during the convective cooling period from km 7-13 in WIND. This decrease also resulted in a difference in pattern of TS scores during the trial (F=19.7, P<0.001). In FALSE-NEG, the pattern of TS during the time trial paralleled the pattern of $T_{sk}$ and is characterized by a sharp decrease after the start of the convective cooling. Scores for TS (1.9 ± 0.1) were similar to WIND (1.8 ± 0.3; P=1.00) and lower than CONTROL (2.4 ± 0.2; P=0.005). In the FALSE-POS subgroup, TS was higher in FALSE-POS (2.5 ± 0.1) than in WIND (1.9 ± 0.2; P=0.02), and similar to TS in CONTROL (2.5 ± 0.1; P=1.00). No effect of the deception was visible in the TS pattern during the time trial.

TC was higher during the cycling TT for CONTROL than for WIND from km 8 onwards (CONTROL: 3.0 ± 0.1, WIND: 2.8 ± 0.2; F=4.45, P=0.05). In FALSE-NEG, TC showed a non-significant decrease from 2.6 ± 0.9 (km 6) to 2.4 ± 0.9 (km 8; P=0.35) and remained lower than CONTROL until km 18. No difference was found between FALSE-NEG and WIND (F=0.69, P=0.52). In FALSE-POS, TC was higher than in WIND from the start of the convective cooling (km 7) until the end of the cooling (km 13). After km 13, no differences were observed between conditions (F=2.80, P=0.10).

**DISCUSSION**

The main goal of this study was to investigate the effect of false information about receiving cooling on pacing pattern and overall performance of a 20-km cycling TT in the heat. Participants were deceived about the occurrence of convective cooling during the mid-portion of the TT in order to separate the effect of the expectation of receiving cooling from the actual effect of the cooling itself. We observed that the pacing pattern during the TT was affected by the expectation of receiving cooling whereas finish time remained similar.

In this study, we used a block-shaped protocol to investigate the effects of the expectation of receiving cooling as well as the effects of the actual cooling itself. All participants
started the TT in the heat without any cooling and depending on the experimental condition they did (WIND, FALSE-NEG) or did not (CONTROL, FALSE-POS) receive convective cooling from km 7-13. From km 13 onwards, no cooling was provided in any of the conditions. The absence of cooling from the start until km 7 allowed us to investigate the effects of the expectation of receiving cooling. The differences in pacing and (psycho-)physiological parameters during this period cannot be attributed to the direct effect of the convective cooling, and therefore possible effects are solely due to the participants’ expectations about receiving cooling from km 7-13. By comparing the pacing pattern and (psycho-)physiological responses between the deceptions trials and CONTROL/WIND, conclusions can be drawn about the effect of the expectation of receiving cooling. The cooling was stopped at km 13 to observe possible differences in the end-spurt phenomenon in comparable environmental conditions.

Although the effect of heat stress on self-paced exercise performance has been investigated in several studies (Tatterson et al. 2000; Tucker et al. 2006; Tucker et al. 2004), only few studies looked at the effect of cooling during exercise on self-paced exercise performance (Tyler et al. 2010; Teunissen et al. 2013; Tyler and Sunderland 2011a). Similar to these studies, we observed a reduced performance in the heat and a beneficial effect of cooling on finish time (40 s faster in WIND than in CONTROL, approximately 2% of time to completion). Although participants started the TT at a similar PO in CONTROL and WIND, a considerable difference started to occur even before the start of the convective cooling (from km 4 until the finish). However, no differences in $T_{re}$, $\overline{T}_{sk}$, and HR were observed at that segment of the TT. Moreover, no differences were found in TS, TC and RPE at this moment, indicating that the physiological strain and the sensations experienced by the participants were similar in CONTROL and WIND. The lower PO that is observed in CONTROL before km 7 (start of the convective cooling) therefore seems to be the consequence of an anticipatory reduction in number of motor units that is recruited. Since the only difference between the two trials is the cooling during the mid-portion of the TT, we can assume that the participants anticipated how difficult it would be to dissipate heat in both conditions and adjusted the number of recruited motor units based on this expectation (Tucker et al. 2004). From km 7 onwards, differences in $\overline{T}_{sk}$ and
associated differences in TS and TC likely resulted in the continuation of the higher PO in WIND compared to CONTROL. As an end-spurt was observed in both conditions, we can conclude that the participants exercised with reserve in CONTROL as well as in WIND (St Clair Gibson and Noakes 2004). Interestingly, RPE was lower in WIND than in CONTROL from km 7 onwards, whereas PO was higher. Because the RPE/PO ratio was also lower for WIND than for CONTROL from this moment on, the convective cooling apparently reduced the relative contribution of exercise intensity to the perceived exertion, indicating the importance of thermal afferent signals in the anticipatory/feedback regulation of exercise intensity (Tucker and Noakes 2009). Based on the lower RPE in WIND compared to CONTROL, we expect that the PO in WIND could have been even higher and that the participants were holding back, perhaps because of their inexperience with the effects of the convective cooling. This notion is supported by the less linear increase in RPE in WIND than in CONTROL (Swart et al. 2009).

To separate the effect of the expectation of receiving cooling from the effect of the cooling itself, participants were deceived about the occurrence of cooling during km 7-13 of the cycling TT. In FALSE-NEG, participants were informed that they were not going to receive convective cooling, whereas they did get cooling. Since this was told to the participants when the fans were turned on at km 7, the pacing pattern until km 7 was (as expected) similar to CONTROL and the mean PO during this period was lower than in WIND. This finding indicates that the pacing strategy for a TT in the heat is not only influenced by thermal status of the human body and associated thermal sensations (Schlader et al. 2011b), but also by expectations regarding the ‘thermal challenge’ during exercise. These findings are in agreement with the observations of Castle et al. (2012), who observed a difference in mean power output in a 30-min cycling TT after deceiving participants about the environmental temperature and their own core temperature. In their study, PO was higher from the start onwards and this resulted in a greater distance completed in the deception trial than in the hot trial, whereas the actual temperatures were similar in both trials. In our study, from km 7 onwards, the pacing pattern appeared to switch over to the WIND-profile and PO was higher for FALSE-NEG than for CONTROL during km 8-13. These observations suggest that although the initial pacing strategy is
The effect of deceptive information about receiving cooling on pacing during a 20-km cycling TT based on expectations of the upcoming TT, the pacing pattern during a TT in the heat can be modified by feedback from (thermo)physiological signals such as skin temperature (Schlader et al. 2011b), core temperature (Marino et al. 2004) and thermal perceptions (Schlader et al. 2011a). More research is needed to evaluate the effect of these thermal afferent signals on self-paced exercise, especially because this effect appears to be influenced by the duration of the exercise bout (Barwood et al. 2012; Levels et al. 2012). Interestingly, after removing the convective cooling at km 13, differences in PO between conditions disappeared, although differences in \( T_{sk} \), TS, and TC were still present. Because the finish of the TT was relatively soon after ending the convective cooling, it seems that the small difference in \( T_{sk} \) and accompanying differences in TS and TC that originated during the convective cooling were not strong enough to alter pacing pattern during the final part of the TT. This notion is reinforced by the comparable RPE and RPE/PO scores after the cooling was stopped, resulting in similar hazard scores in FALSE-NEG, CONTROL, and WIND (de Koning et al. 2011).

In FALSE-POS, the participants were informed that they were going to receive convective cooling during the mid-portion of the TT, whereas they did not get it. Although we expected a pacing pattern similar to WIND during km 0-7, no differences in power output were observed between conditions in this period. The same was true for the period from km 7-20, during which we expected a pacing pattern similar to CONTROL. However, it has to be noted that, although not statistical significant, PO seems to decline in CONTROL and FALSE-POS and remains stable in WIND. These observations are similar to the findings of Hartley et al. (2011) who used a block design in which they altered the ambient temperature from 20°C to 35°C and back again. As participants were only aware of this manipulation when it began, the effect of the expectation of the upcoming manipulation was removed. Main finding in this study was that changes in thermophysiological signals did not influence self-selected power output in this fixed-RPE trial, suggesting a strong role for the originally determined pacing strategy.

Because of the deceptive nature of this study, participants could only complete one misleading trial (either FALSE-NEG or FALSE-POS). Therefore, we opted to divide the group
of participants into two subgroups who completed either FALSE-NEG or FALSE-POS. Although this resulted in a reduction in statistic power, we were able to investigate the effect of both types of expectation on self-paced performance and associated physiological responses. Since we observed that PO was already altered before the intervention was started, it appears that the knowledge of an upcoming thermal manipulation is important for the constitution of the initial pacing strategy. Moreover, in FALSE-NEG misleading seems to have more impact on the pacing pattern than FALSE-POS. In FALSE-NEG the subjects start out at low power, expecting no cooling. When the cooling commences, the subjects realize that they can do better and PO goes up considerably. In FALSE-POS, however, the subjects started cycling hard expecting the convective cooling. When this suddenly appears to be absent, the PO gradually declines, but sufficient resources remain for an end-spurt. These findings indicate that the participants exercise with reserve (St Clair Gibson and Noakes 2004) and that deceiving athletes about the occurrence of cooling during self-paced exercise can be a way to access the physiological reserve and obtain an effort that is closer to the ‘real’ maximum effort (Jones et al. 2013). In summary, the knowledge of an upcoming (thermal) intervention can seriously impact performance and if the pure effect of an intervention on pacing pattern is investigated, all efforts should be made to blind participants to the experimental condition. Because no effect on finish time was observed, the knowledge of an upcoming intervention appears to be relatively unimportant for subsequent performance. Therefore, we suggest that in real-life competition deceiving athletes regarding environmental conditions should be avoided, moreover because an athlete can only be successfully deceived one time and the coach-athlete relationship can be seriously affected by giving false information to the athlete.

CONCLUSION

Not only the convective cooling itself, but also the expectation of receiving cooling alters pacing pattern but does not affect finish time of a 20-km cycling time trial in the heat. Therefore, when investigating the effect of an intervention on self-paced exercise, the
The effect of deceptive information about receiving cooling on pacing during a 20-km cycling TT

intervention itself, but also the expectation that participants have about the intervention should be taken in account.