

Talking Yourself Out of Exhaustion: The Effects of Self-talk on Endurance Performance

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¹Institute for the Psychology of Elite Performance (IPEP), School of Sport, Health and Exercise Sciences, Bangor University, Bangor, UNITED KINGDOM; ²Department of Medical and Clinical Psychology, Center of Research on Psychology in Somatic diseases (CoRPS), Tilburg University, Tilburg, THE NETHERLANDS; and ³Endurance Research Group, School of Sport and Exercise Sciences, University of Kent, Kent, UNITED KINGDOM

ABSTRACT

BLANCHFIELD, A. W., J. HARDY, H. M. DE MORREE, W. STAIANO, and S. M. MARCORA. Talking Yourself Out of Exhaustion: The Effects of Self-talk on Endurance Performance. *Med. Sci. Sports Exerc.*, Vol. 46, No. 5, pp. 998–1007, 2014. **Purpose:** The psychobiological model of endurance performance proposes that the perception of effort is the ultimate determinant of endurance performance. Therefore, any physiological or psychological factor affecting the perception of effort will affect endurance performance. Accordingly, this novel study investigated the effects of a frequently used psychological strategy, motivational self-talk (ST), on RPE and endurance performance. **Methods:** In a randomized between-group pretest–posttest design, 24 participants (mean $\pm$ SD age = 24.6 ± 7.5 yr, $\dot{V}O_{2\max} = 52.3 \pm 8.7$ mL $\cdot$ kg $^{-1}\cdot$ min $^{-1}$) performed two constant-load (80% peak power output) cycling time-to-exhaustion (TTE) tests, punctuated by a 2-wk ST intervention or a control phase. **Results:** A group (ST vs Control) $\times$ test (pretest vs posttest) mixed-model ANOVA revealed that ST significantly enhanced TTE test from pretest to posttest (637 ± 210 vs 750 ± 295 s, $P < 0.05$) with no change in the control group (486 ± 157 vs 474 ± 169 s). Moreover, a group $\times$ test $\times$ isotime (0%, 50%, and 100%) mixed-model ANOVA revealed a significant interaction for RPE, with follow-up tests showing that motivational self-talk significantly reduced RPE at 50% isotime (7.3 ± 0.6 vs 6.4 ± 0.8 , $P < 0.05$), with no significant difference in the control group (6.9 ± 1.9 vs 7.0 ± 1.7). **Conclusions:** This study is the first to demonstrate that ST significantly reduces RPE and enhances endurance performance. The findings support the psychobiological model of endurance performance and illustrate that psychobiological interventions designed to specifically target favorable changes in the perception of effort are beneficial to endurance performance. Consequently, this psychobiological model offers an important and novel perspective for future research investigations. **Key Words:** PERCEPTION OF EFFORT, PSYCHOBIOLOGICAL MODEL, ISOTIME, PSYCHOLOGICAL STRATEGY

The increased popularity of endurance sports in recent decades has coincided with a substantial growth in the number of individuals taking part in endurance-based events. As such, the use of performance-enhancing strategies is relevant for many competitors when training or taking part in these events. A key aspect of performance in most endurance sports is the ability to sustain aerobic exercise over prolonged periods. The upper limit to this ability, commonly called exhaustion, is traditionally thought to represent the culmination of progressive muscle fatigue (1,2,24). Consequently, strategies designed to enhance the performance of endurance competitors frequently target

the musculoenergetic and cardiovascular elements of endurance (24).

Alternatively, the psychobiological model of endurance performance (29–31), based on motivational intensity theory (7), posits that exhaustion is caused by the conscious decision to terminate endurance exercise, as opposed to muscle fatigue (30). As such, an individual will terminate endurance exercise either when the effort required by the task exceeds the greatest amount of effort that the individual is willing to exert during the task (potential motivation), or when maximal effort is considered to have occurred and continuation of the task is perceived as impossible (29–31).

According to this psychobiological model, the ultimate determinant of endurance performance in highly motivated subjects is the perception of effort, defined as the conscious sensation of how hard, heavy, and strenuous exercise is (32). Therefore, it is predicted that any physiological or psychological factor affecting the perception of effort will affect endurance performance (29,30). In support of this perspective, interventions such as sleep deprivation (33), naloxone administration (40), and mental fatigue (30) have been shown to elevate RPE and hinder endurance performance, whereas interventions such as physical training (13), nutritional intake

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(5), and psychostimulant manipulations (12,22) have been shown to reduce RPE and enhance endurance performance. The enhancement of endurance performance through strategies that specifically target a reduction in the perception of effort is therefore appealing. To date, however, the scope of strategies that are designed for this purpose remains narrow. Moreover, other than the effects of music (25) and associative/dissociative attentional techniques (28), the exploration of psychological strategies within this context seems minimal. The identification of psychological strategies that are able to reduce the perception of effort and enhance endurance performance therefore warrants further investigation.

One widely used psychological strategy that has been postulated to favor effort-based tasks is self-talk (18). Self-talk has been defined as a multidimensional phenomenon concerned with athletes' self-addressed verbalizations that can serve both instructional and motivational functions (14). This definition is based on the results of qualitative data analyses revealing that self-talk can be broadly categorized as instructional or motivational (18). Moreover, motivational self-talk used during exercise can be further divided into the auxiliary components of arousal, mastery, and drive (14).

It has been noted that the effort oriented motivational drive function represents the most frequently reported reason for the use of self-talk during exercise, most prevalently toward the end of the workout when the desire to terminate exercise is at its strongest (14). As such, it has been proposed that motivational self-talk should be effective at not only enhancing motivation but at regulating effort (18). Corresponding to the psychobiological model of endurance performance, this suggests that motivational self-talk might be an effective psychological strategy for the enhancement of endurance performance. To date, however, many studies that have investigated the use of self-talk during endurance performance have done so within the framework of psychological skills packages (4,43). As acknowledged by these investigations, this makes the precise benefit of individual components such as self-talk difficult to evaluate. Despite this, the completion of postexperimental questionnaires has indicated that participants find self-talk to be an effective psychological strategy (4). Even so, very few studies have explored the effects of self-talk on endurance performance in isolation. Furthermore, no investigation has examined the effects of motivational self-talk on RPE during endurance exercise. For example, it has been found that assisted positive self-talk, self-regulated positive self-talk, and assisted negative self-talk each enhanced work output during 20-min cycling exercise (16). Nonetheless, the multiple baseline single-subject design provided no indication of statistical analysis thus making the findings difficult to interpret and generalize. Furthermore, physiological and perceptual measures were lacking, making it difficult to determine the mechanisms behind the enhanced work output. Similarly, the effect of self-addressed verbalizations on performance has been investigated at specific race points during a marathon (38). However, despite finding that self-addressed verbalizations correlated with improved

performance, once more physiological and perceptual measures were lacking. Moreover, the nonexperimental nature of this study makes it difficult to establish a causal relationship between the use of self-talk and the improved endurance performance.

The primary aim of the present study was to investigate experimentally the effect of self-talk on endurance performance during high-intensity cycling exercise. A time-to-exhaustion (TTE) test was selected as this test has been shown to be a sensitive measure of endurance performance (3). Furthermore, we measured the perception of effort using RPE and a recently developed psychophysiological measure based on the facial expression of effort (10). We hypothesized that motivational self-talk would reduce RPE during high-intensity cycling exercise and that this would increase time to exhaustion.

METHODS

Participant Characteristics and Ethics

Twenty-four recreationally trained individuals (15 men and 9 women; mean $\pm$ SD, age = 24.6 ± 7.5 yr, height = 176 ± 7 cm, weight = 72.7 ± 10.1 kg, peak power output [PPO] = 313 ± 69 W, maximum oxygen uptake [$\dot{V}O_{2\max}$] = 52.3 ± 8.7 mL $\cdot$ kg $^{-1}\cdot$ min $^{-1}$) volunteered to take part in the study. All participants were healthy, free from injury, and recreationally engaged in a range of individual- or team-based aerobic sports on a minimum of two occasions per week with an average session duration of 83.3 ± 29.3 min. Before taking part, all participants completed a standard medical questionnaire to confirm their present state of health along with an informed consent form approved by the ethics committee of the School of Sport, Health and Exercise Sciences, Bangor University, UK. Participants were provided with a detailed overview of all procedures and requirements of the study before its commencement but remained naive to the aims and hypotheses. In addition, on the cessation of the study, participants were debriefed as to its nature and were requested not to discuss the study with other participants.

Study Design and Procedures

The study consisted of a controlled pretest–posttest design in which participants visited the laboratory on three separate occasions and were randomized into two independent groups ($N = 12$) after the second visit. The control group contained seven men and five women, whereas the self-talk group contained eight men and four women. All exercise tests were conducted in the same location on the same electromagnetically braked cycle ergometer (Excalibur Sport, Lode, Groningen, the Netherlands), with saddle and handlebar specifications adjusted to suit the preference of each subject and maintained for each visit. During visit 1, each participant first completed an informed consent questionnaire and an instruction checklist, after which anthropometric measurements were recorded. An incremental test was then carried out to establish PPO and $\dot{V}O_{2\max}$. The incremental

test began with a 2-min rest, after which power output was increased by 50 W every 2 min until volitional exhaustion. Exhaustion was operationally defined as a reduction in cadence below 60 revolutions per minute (rpm) for five consecutive seconds despite strong verbal encouragement. For the incremental test, the cycle ergometer was set in hyperbolic mode, which allows the power output to be set independently of cadence over a range of 30–120 rpm, and the participant was instructed to remain in the saddle at all times. $\dot{V}O_{2\max}$ was measured breath by breath via a computerized metabolic gas analysis system (Metalyzer 3B; Cortex Biophysik, Leipzig, Germany) connected to an oro-(mouth) mask (7600 series; Hans Rudolph, Kansas City, MO). The device was calibrated before each incremental test using a known concentration of gases and a 3.0-L calibration syringe (Series 5530; Hans Rudolph). PPO was calculated according to the equation of Kuipers et al. (26). Resting HR was recorded 15 s from the end of the 2-min rest using wireless chest strap radio telemetry (S610; Polar Electro, Kempele, Finland) and was then measured every minute during the incremental test thereafter. RPE was also recorded every minute during the incremental test using the CR10 scale (for details, see the Perceptual and Psychophysiological Measures of Effort section).

During visit 2, participants first completed an instruction checklist followed by separate mood and motivation questionnaires (for details, see the Psychological Questionnaires section). After this, participants completed a TTE test. For the TTE test, subjects were positioned on the cycle ergometer (set to hyperbolic mode) and instructed to remain in the saddle at all times. The TTE test commenced with a 3-min warm-up at 40% of the participants PPO. After 3 min, the power output was automatically increased to a power output corresponding to 80% PPO. Cadence was freely chosen between 60 and 100 rpm and was recorded every minute during the task. RPE was also recorded at 1-min intervals using the CR10 scale along with HR (for details, see the Additional Physiological Measures section). Bipolar single differential surface EMG was recorded from the corrugator supercilii throughout (for details, see the Perceptual and Psychophysiological Measures of Effort section). Time to exhaustion was defined as the time accrued from the onset of the 80% PPO until the point at which cadence had fallen below 60 rpm for five consecutive seconds. No verbal encouragement was provided at any point during the TTE test so as to eliminate the superimposition of any extraneous verbal statements. A fan was placed approximately 60 cm in front of the cycle ergometer. Participants were provided with the option of being tested with or without the use of the fan and completed the subsequent TTE test under identical conditions. To avoid bias from mimicry and audience effects on facial EMG measurements, the experimenter stood behind participants at all times (41). Three minutes after exhaustion, participants provided a blood sample for lactate concentration analysis (for details, see the Additional Physiological Measures section). Random allocation took place at this point (www.randomization.com), with participants allocated to the

self-talk group carrying out a two-stage intervention over the ensuing 2 wk (for more details, see Motivational Self-talk Intervention section), whereas participants allocated to the control group received no intervention. Both groups were instructed to continue with their usual aerobic exercise regimen during this 2-wk period.

All testing procedures carried out during visit 2 were replicated during visit 3; participants in the self-talk group were reminded to make use of their four self-talk statements during the TTE test. At the end of visit 3, all participants completed a manipulation check questionnaire (for details, see the Manipulation Checks section) and remained naive to their cycling times during visits 2 and 3 until the debriefing that followed the manipulation checks.

Visits 1 and 2 were separated by a minimum of 72 h, whereas visits 2 and 3 were punctuated by a minimum of 14 d, during which the motivational self-talk intervention (self-talk group) or usual exercise without the self-talk intervention (control group) took place. All participants visited the laboratory at a similar time of day for each of their visits. As instructed before each visit, participants maintained similar dietary patterns during the preceding 24 h while consuming an amount of water equivalent to least 35 mL·kg⁻¹ body weight and attaining at least 7 h of sleep the night before. Participants also avoided any heavy exercise in the 24 h before testing and refrained from the consumption of caffeine and nicotine in the 3-h period leading up to each test. Finally, participants voided before each test and performed during all visits in similar clothing.

Motivational self-talk intervention. Analogous to Thelwell and Greenlees (43), the motivational self-talk intervention was administered in two stages and involved the use of a workbook. Stage 1 occurred after the first TTE test (pretest) and comprised of a 30-min introduction to self-talk along with the identification and development of four motivational self-talk statements. Stage 2 consisted of the practical use of these statements during their customary aerobic exercise sessions throughout the 2-wk intervention. This format was used to facilitate the personalized and practiced use of each statement.

During stage 1, participants were introduced to the concept of self-talk and provided with a workbook in which they highlighted any self-talk statements that they had used in the preceding TTE test. From this pool of self-statements, participants identified up to five that were deemed to be motivational and compared them to a set of 12 prelisted motivational statements (e.g., “drive forward” and “you’re doing well”) generated from the existent self-talk literature. From these two lists, participants were requested to select four statements that would optimize their performance during a TTE test identical with the one previously carried out. It was instructed that two of these statements should be relevant to the early–mid stage of such test (e.g., “feeling good”), with the remaining two being more applicable to the last stage of the test near exhaustion (e.g., “push through this”). This approach was chosen so as to identify the contextual

influence of verbal statements (27) on specific stages of the TTE test.

Stage 2 was a familiarization phase in which participants were instructed to continue with their own training while using their selected statements, during a minimum of three aerobic exercise sessions over the 2-wk period. After each aerobic exercise session, participants completed a workbook protocol to assist them in assessing the use and efficacy of each of their four chosen statements during the session. Effective statements were noted and used in the subsequent aerobic exercise sessions, whereas ineffective statements were either rephrased or replaced with a more suitable statement (as deemed by the participants). This process was designed to ensure that participants were comfortable using their four motivational self-statements when they performed the second TTE test (posttest).

Manipulation checks. After the second TTE test (posttest), each participant completed a questionnaire-based manipulation check. For both groups, this manipulation check assessed adherence to their respective manipulation instructions on an 11-point Likert-type scale (0 = not at all, 10 = greatly). The remainder of the manipulation check questionnaire was specific to each group. The manipulation check for the self-talk group was designed to measure the extent of self-talk usage during the TTE test. The manipulation check for the control group was designed to disclose any use of self-talk during the TTE test. If participants in the control group used some form of self-talk, space was allocated to reveal each statement used along with its extent of use, measured on an 11-point Likert-type scale (0 = rarely, 10 = very often). For the self-talk group, space was allocated to highlight each motivational self-talk statement that they had used during the TTE test, both designated and undesignated. Again the extent of use for each statement was also indicated.

Perceptual and psychophysiological measures of effort. RPE was measured using the 11-point CR10 scale developed by Borg (6). Low (0.5 = very, very light) and high (10 = maximal) anchors were established using standard procedures (36). Participants were also free to rate a value higher than 10 if they perceived their state of effort as higher than any previous maximal effort experienced. Standardized instructions for perceived exertion were provided to all participants before each test, with the emphasis that each rating should be based on the effort required to perform the TTE test as opposed to any leg muscle pain occurring during high-intensity cycling exercise.

Facial EMG has been shown to be a valid psychophysiological measure of perceived effort during a TTE test of similar exercise intensity (11). Therefore, bipolar single differential surface facial EMG amplitude was recorded from the left and right corrugator supercilii muscles throughout the TTE test. Before electrode placement, the site above the brows was cleaned with an alcohol swab and the skin carefully dried with a tissue. On each side of the face, one pregelled Ag/AgCl electrode (Neuroline 720-00-S; Ambu Inc., Ølstykke, Denmark; recording area = $\varnothing$ 11 mm) was

attached lateral to the glabellar midline. An additional electrode was attached immediately lateral to each of these placements just superior to the medial border of the eyebrow with a 40-mm interelectrode distance (10). A ground strap was then placed around the wrist of the participant. The EMG signals were amplified by a multichannel EMG amplifier (EMG 16; OT Bioelettronica, Torino, Italy; bandwidth = 10–500 Hz, fourth-order Bessel low-pass filter) fed into a 12-bit acquisition board (DAQCard-6024E; National Instruments Corporation, Austin, TX) at a sampling rate of 2048 Hz, displayed on a PC, and recorded for later offline analysis. Participants were unaware of the real purpose of the facial electrodes and were told that they were used to measure brain activity. EMG data were analyzed offline using Matlab version 7.12. The data were filtered with a zero-lag, band-pass, fourth-order Butterworth filter (cutoff frequencies = 20 and 400 Hz). The root mean square of the facial EMG data was calculated for 1-min periods.

Additional physiological measures. HR was recorded throughout the TTE test using wireless chest strap radio telemetry (S610; Polar Electro). Before testing, the chest strap was wetted and securely fastened to the participant's chest according to the manufacturer's guidelines. Lactate concentration was measured by collecting 5 μ L of whole fresh blood from the earlobe 3 min after the TTE test. Each blood sample was immediately analyzed using a calibrated device (Lactate Pro LT-1710; Arkray, Shiga, Japan).

Psychological questionnaires. The Brunel Mood Scale (BRUMS) was used to assess mood before each TTE test. This abbreviated 24-item profile of mood states has been validated for use with adult populations (42). This mood questionnaire includes six subscales (anger, confusion, depression, fatigue, tension, and vigor) with four items per subscale. Items were answered on a 5-point Likert-type scale (0 = not at all, 1 = a little, 2 = moderately, 3 = quite a bit, 4 = extremely).

Motivation was measured via the success motivation and intrinsic motivation scales developed and validated by Mathews et al. (34). Each subscale consists of seven items on a 5-point Likert-type scale with identical anchors to those described earlier.

Statistical analyses. Unless otherwise noted, data are shown as mean $\pm$ SD. Age, $\dot{V}O_{2\max}$, and PPO were assessed for between-group differences using independent *t*-tests. Manipulation checks were also assessed using independent *t*-tests to check for group differences in adherence to task instructions, number of self-talk statements used during the second TTE test (posttest), and also their mean extent of use. After checking relevant parametric assumptions, group $\times$ test ANOVA was assessed for the effects of motivational self-talk on mood and motivation, time to exhaustion, mean cadence and various measures at exhaustion (RPE, facial EMG amplitude, HR, and blood lactate concentration). If assumptions of sphericity were violated, the Greenhouse–Geisser correction was used, and Tukey's HSD *post hoc* tests were calculated where appropriate. Group $\times$ test $\times$ time ANOVA were used to test the effects of motivational self-talk on RPE, facial EMG amplitude, HR, and cadence at 0% (first minute), 50%, and 100% (final full

minute completed) of time to exhaustion. These variables were measured at the selected time points to allow the within-group comparison of temporal changes that may arise during the TTE test. To obtain this isotime data, the value of each parameter at 100% isotime was established by identifying the shortest time to exhaustion accomplished by each individual over their two tests. The value for each variable attained during the final full minute of the shortest TTE test was then compared with the value attained during the equivalent minute of the longer TTE test. The minute identified as 100% isotime was divided by two and rounded up where necessary to attain the value corresponding to 50% isotime. Isotime values for 0% were attained by comparing values for the first full minute of each TTE test. Cohen's d (9) values are provided as an estimate of effect size where relevant. Thresholds for trivial, small, moderate, or large effect sizes were set at <0.2, 0.2, 0.5, and 0.8, respectively (9). Statistical significance was set at $P < 0.05$ (two-tailed) for all analyses, and all data analysis was conducted using the Statistical Package for the Social Sciences (version 14; SPSS Inc., Chicago, IL).

RESULTS

Group characteristics and manipulation checks. Age, $\dot{V}O_{2\max}$, and PPO were not statistically different between groups (see Table 1), whereas the manipulation check questionnaire revealed that both groups adhered equally to their task instructions, $t(21) = -1.01$, $P = 0.32$. Given the nature of self-talk, it is unsurprising that 10 of the 12 participants in the control group reported limited use of self-talk. However, compared with the self-talk group, self-talk within the control group was used infrequently. The self-talk group used significantly more self-talk statements than the control group, $t(22) = -3.9$, $P = 0.001$ (4.1 ± 1.5 vs 1.8 ± 1.4), and to a significantly greater extent, $t(15.48) = -2.16$, $P = 0.047$ (6.9 ± 1.4 vs 4.9 ± 2.9). Motivational self-talk was therefore used differently and more extensively in the self-talk group compared with the control group.

Effects of self-talk on mood and motivation before the TTE test. Participants commenced the TTE test during each visit in similar mood, as indicated by the fact that no group–test interactions or main effects of test were present for ratings on all BRUMS subscales (see Table 2). Also, no group–test interactions or main effects of test were present for success motivation and intrinsic motivation with mean ratings

for each of these scales, signifying that participants in both groups were highly motivated to participate and perform well in the TTE test on both occasions (see Table 2).

Effect of self-talk on time to exhaustion. As predicted, motivational self-talk had a significant effect on time to exhaustion (group–test interaction, $F_{1,22} = 8.01$, $P = 0.01$, $d = 0.69$). Follow-up tests revealed that time to exhaustion increased significantly from pretest (637 ± 210 s) to posttest (751 ± 295 s) in the self-talk group ($P < 0.05$). Moreover, all but two of the participants randomized to the motivational self-talk intervention improved their time to exhaustion. In comparison, time to exhaustion in the control group did not change significantly across tests (pretest = 487 ± 157 s, posttest = 475 ± 169 s) (see Fig. 1). Pretest time to exhaustion was significantly different between groups however. Consequently, further analysis was carried out using ANCOVA, whereby baseline TTE test was controlled as the covariate. Accordingly, the effect of motivational self-talk on TTE test remained significant ($F_{1,21} = 4.49$, $P = 0.046$).

Effects of self-talk on RPE, facial EMG amplitude, HR, and blood lactate concentration at exhaustion. No significant group–test interaction or main effect of test was present for RPE at exhaustion. Importantly, RPE values at exhaustion indicated that participants in both groups disengaged from the TTE test on reaching maximal effort during both the pretest and the posttest visits (see Table 3 and Fig. 2). Similarly, no group–test interactions and main effects of test were evident for facial EMG amplitude throughout the last full minute before exhaustion, HR at exhaustion, and blood lactate concentration sampled 3 min after exhaustion (see Table 3).

Effects of self-talk on cadence, HR, facial EMG amplitude, and RPE at isotime during the TTE test. The mean calculated isotimes were greater for the self-talk group at both 50% and 100% with mean 50% isotime occurring at 315 ± 109 s for the self-talk group in comparison with 230 ± 80 s for the control group and mean 100% isotime occurring at 624 ± 228 s for the self-talk group and 430 ± 163 s for the control group. Isotime data for cadence, HR, facial EMG amplitude, and RPE are reported in Table 4.

Motivational self-talk had a significant effect on cadence at isotime (group–test–isotime interaction, $F_{2,40} = 8.34$, $P = 0.01$). Follow-up tests revealed no significant effect of motivational self-talk at 0% isotime and 50% isotime. A significant group–test interaction was present at 100% isotime ($F_{1,20} = 11.46$, $P = 0.003$, $d = 2.2$). Further follow-up tests revealed that cadence was significantly greater in the self-talk group at 100% isotime during posttest compared with pretest visit ($P < 0.05$). No significant difference between pretest and posttest was found for cadence at 100% isotime in the control group.

Motivational self-talk did not affect HR and facial EMG amplitude, with no significant group–test–isotime interactions present for these variables. However, as expected, both HR (main effect of isotime, $F_{1,41,29,57} = 203.62$, $P < 0.001$) and facial EMG amplitude (main effect of isotime, $F_{2,44} = 10.43$,

TABLE 1. Participant characteristics for control group and self-talk group.

	Age (yr)	$\dot{V}O_{2\max}$ (mL·kg ⁻¹ ·min ⁻¹)	PPO (W)
Control ($n = 12$)	25.0 $\pm$ 9.2	52.7 $\pm$ 8.7	306.2 $\pm$ 70.5
Males ($n = 7$)	28.7 $\pm$ 10.1	56.0 $\pm$ 8.7	352.4 $\pm$ 39.0
Females ($n = 5$)	19.8 $\pm$ 1.5	48.0 $\pm$ 7.8	241.5 $\pm$ 34.3
Self-talk ($n = 12$)	24.3 $\pm$ 6.2	51.8 $\pm$ 9.1	319.5 $\pm$ 72.6
Males ($n = 8$)	25.4 $\pm$ 7.2	56.0 $\pm$ 6.0	361.0 $\pm$ 23.7
Females ($n = 4$)	22.0 $\pm$ 3.6	43.5 $\pm$ 9.0	236.5 $\pm$ 65.0

Data are presented as mean $\pm$ SD.
PPO, peak power output.

TABLE 2. Ratings for all BRUMS subscales and success and intrinsic motivation scales.

		BRUMS Subscales						Motivation	
		Anxiety	Confusion	Depression	Fatigue	Tension	Vigor	Success	Intrinsic
Pre	Con	0.7 ± 1.6	1.6 ± 2.4	0.3 ± 0.7	2.8 ± 1.9	2.7 ± 1.4	9.9 ± 3.2	20.6 ± 4.3	23.2 ± 2.9
	ST	0.8 ± 1.7	1.9 ± 3.0	0.9 ± 2.2	2.6 ± 2.2	2.9 ± 1.4	8.7 ± 2.3	21.4 ± 4.4	23.5 ± 3.4
Post	Con	0.7 ± 1.3	1.1 ± 1.7	1.3 ± 1.9	3.4 ± 2.4	3.2 ± 1.6	10.8 ± 1.8	19.4 ± 5.1	24.0 ± 2.1
	ST	0.9 ± 2.5	2.7 ± 3.0	1.0 ± 2.8	3.4 ± 2.8	2.9 ± 1.7	8.4 ± 2.9	19.0 ± 7.0	22.8 ± 2.7

Data are presented as mean ± SD.
Pre, preintervention visit; Post, postintervention visit; Con, control group; ST, self-talk group.

$P < 0.01$) increased significantly over isotime regardless of treatment or visit.

As hypothesized, motivational self-talk had a significant effect on RPE at isotime (group–test–isotime interaction, $F_{2,49} = 3.85$, $P = 0.029$) (see Fig. 2). Follow-up tests revealed no significant effect of motivational self-talk on RPE at 0% isotime, demonstrating that RPE was equal between groups at the onset of the TTE test (control: pretest = 4.3 ± 1.6 , posttest = 3.8 ± 1.6 ; self-talk: pretest = 4.0 ± 1.0 , posttest = 3.5 ± 0.7). The effects of motivational self-talk on RPE were however demonstrated by a significant group–test interaction at 50% isotime ($F_{1,22} = 6.7$, $P = 0.017$, $d = 0.80$), with a significant reduction in RPE at posttest (6.4 ± 0.8) compared with pretest (7.3 ± 0.6) in the self-talk group ($P < 0.05$) and no statistical difference between pretest (6.9 ± 1.9) and posttest (7.0 ± 1.7) in the control group. A comparable, but non-significant, trend was present for motivational self-talk at 100% isotime (group–test, $F_{1,22} = 2.99$, $P = 0.098$, $d = 0.91$). RPE was lower at posttest (9.0 ± 0.8) compared with pretest (9.8 ± 0.5) in the self-talk group despite a similar RPE in the control group (pretest 9.1 ± 1.7 , posttest 9.3 ± 2.4).

DISCUSSION

This study investigated the effects of motivational self-talk on the perception of effort and endurance performance within the framework of the psychobiological model of en-

durance performance (29–31). As hypothesized, motivational self-talk reduced RPE and increased time to exhaustion during high-intensity cycling exercise. Specifically, motivational self-talk reduced RPE at 50% isotime during the TTE test with a similar but nonsignificant trend at 100% isotime. The present study is therefore unique as it is the first to experimentally demonstrate that motivational self-talk reduces the perception of effort and provides empirical support for previous suggestions that self-talk enhances endurance performance (16, 38). This is an important finding given the absence of experimental support for the asserted effects of motivational self-talk on effort (18) and task termination (14).

The present findings are supported by the established effects of other psychological interventions on endurance performance. For instance, although using a different type of test, a psychological skills package containing self-talk has previously been found to enhance running distance in the heat by 8% (4). The 18% improvement in time to exhaustion in our study depicts the utility of motivational self-talk as a performance-enhancing strategy during endurance exercise and is contextualized by its comparability to the potent performance-enhancing impact of psychostimulant drugs (27%; 22). Crucially, that this improvement was associated with a reduction in RPE exemplifies the degree to which psychological factors may independently affect endurance performance. This reinforces the proposal that the perception

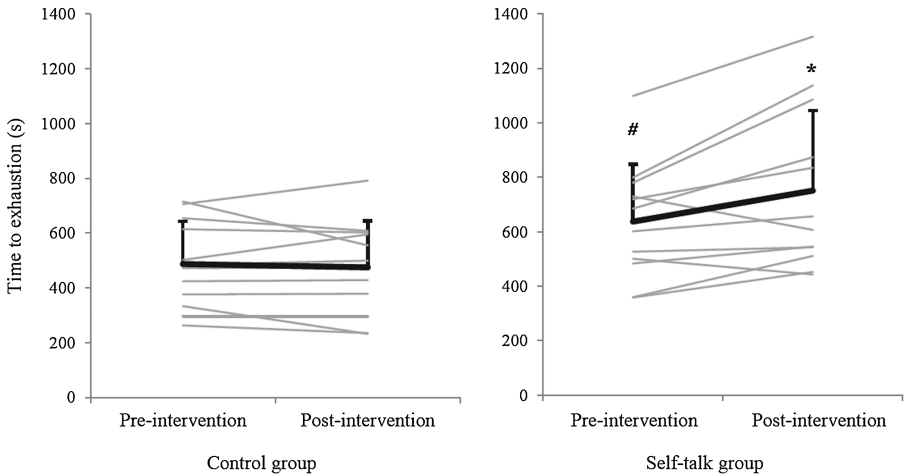


FIGURE 1—Mean ± SEM preintervention to postintervention changes in time to exhaustion for control group and self-talk group (black lines) and individual values for preintervention to postintervention changes within each group (gray lines). *Significant difference between preintervention and postintervention. #Significant difference between groups during corresponding visit.

TABLE 3. Physiological and perceptual measures at exhaustion.

	Control		Self-talk	
	Pre	Post	Pre	Post
Mean Cad (rpm)	77.3 ± 6.2	77.0 ± 9.0	77.5 ± 9.4	81.2 ± 9.0 ^a
End Lac (mmol·L ⁻¹)	9.7 ± 2.8	9.0 ± 1.8	8.5 ± 2.3	8.9 ± 2.5
End HR (bpm)	187.0 ± 10.0	187.3 ± 10.7	182.4 ± 10.3	187.4 ± 11.5
End fEMG Amp (μV)	30.4 ± 25.1	30.4 ± 19.0	51.1 ± 61.2	45.8 ± 47.4
End RPE	9.2 ± 0.7	10.2 ± 2.0	10.1 ± 0.6	10.0 ± 0.3

Data are presented as mean ± SD.

^aSignificantly greater than preintervention visit.

Mean Cad, mean cadence; End Lac, end exercise lactate; End HR, end exercise heart rate; End fEMG Amp, end exercise facial EMG amplitude; End RPE, end exercise perception of effort; Pre, preintervention visit; Post, postintervention visit.

of effort acts as the ultimate determinant of endurance performance (29–31).

Attentional and informational processing frameworks have previously been suggested to account for the performance-enhancing effects of self-talk (17). However, the fact that motivational self-talk instigated a reduction in RPE during the TTE test provides a novel theoretical framework to explain how this strategy can enhance endurance performance: the psychobiological model proposed by Marcora et al. (29–31). The psychobiological model of endurance performance, based on motivational intensity theory (7), suggests that an individual will terminate endurance exercise either when the effort required by the task exceeds his/her potential motivation, or when a true maximal effort is considered to have occurred and continuation of the task is perceived as impossible (29–31). In the present study, we observed a drop of almost 1.0 point in RPE at 50% and 100% isotime when using motivational self-talk during the TTE test. This perceptual effect of motivational self-talk delayed the point at which our highly motivated subjects perceived very high effort and consciously decided to terminate the TTE test. Importantly, however, RPE at exhaustion was near maximal for all subjects and was not statistically different between groups. Popular strategies such as aerobic training (13), nutritional intervention (5), inspiratory muscle training (15), and psychostimulant administration (22) have already demonstrated that a reduction in RPE enhances endurance performance. That a psychological strategy such as

motivational self-talk is able to achieve similar benefits supports our contention that any physiological or psychological factor affecting RPE and/or potential motivation will affect endurance performance (29–31). As RPE is sensitive to both psychological and physiological factors, the framework offered by the psychobiological model provides a unifying explanation for the positive effects of both psychological and physiological strategies on endurance performance. Accordingly, strategies targeting beneficial changes in RPE through this psychobiological framework may offer a new paradigm for endurance performance enhancement.

The present study was not designed to identify how motivational self-talk might cause a reduction in the perception of effort. However, it is possible that the use of motivational self-talk during the TTE test increased the perceived ability of our participants to maintain the required power output for longer. Correspondingly, it is this cognitive effect of motivational self-talk that may have reduced RPE and delayed the point at which a maximal effort was believed to have occurred. In support of this hypothetical cognitive mechanism, the performance benefits that are derived from motivational self-talk have previously been associated with enhanced self-efficacy (18,19). Although a different mode and intensity of exercise to that of the present study, self-efficacy has also been reported to predict 14% of the variance in RPE during 30 min of moderate-intensity running (37). In addition, psychophysiological investigations of motivational intensity

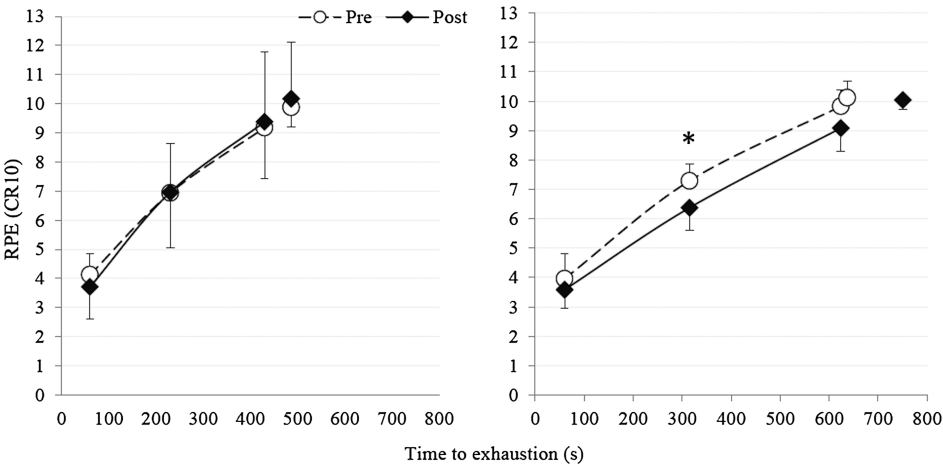


FIGURE 2—Mean ± SEM RPE at isotimes of 0%, 50%, and 100% and at exhaustion for the control group (left) and self-talk group (right). *Significant difference between preintervention and postintervention at a given isotime.

TABLE 4. Cadence, HR, and facial EMG amplitude at 0%, 50%, and 100% isotime during the TTE tests.

	Control			Self-talk		
	0%	50%	100%	0%	50%	100%
Cad (rpm)						
Pre	78.5 ± 6.1	79.2 ± 7.1	71.7 ± 8.4	78.5 ± 11.8	83.0 ± 10.3	66.3 ± 4.8
Post	79.7 ± 9.3	81.7 ± 9.0	73.0 ± 14.23	79.8 ± 11.4	83.0 ± 10.4	82.1 ± 8.6 ^a
HR (bpm) ^b						
Pre	159.8 ± 12.2	178.8 ± 10.4	186.8 ± 9.6	152.0 ± 11.3	174.5 ± 8.9	182.5 ± 10.1
Post	159.7 ± 10.7	179.1 ± 12.2	187.0 ± 12.6	158.0 ± 13.1	177.5 ± 10.9	186.4 ± 11.1
fEMG Amp (μV) ^b						
Pre	12.7 ± 9.7	16.0 ± 13.2	28.5 ± 24.8	10.7 ± 4.4	13.0 ± 5.7	50.4 ± 63.4
Post	12.7 ± 6.6	19.2 ± 15.3	25.2 ± 17.6	11.0 ± 3.6	15.9 ± 10.9	37.5 ± 34.4

Data are presented as mean ± SD.

^aSignificantly greater than preintervention visit.

^bSignificant increase over isotime.

Cad, cadence; fEMG Amp, facial EMG amplitude; Pre, preintervention visit; Post, postintervention visit.

theory have demonstrated that perceived ability can modify effortful behavior. For example, participants with high perceived ability are more willing to exert effort at greater task difficulties whereas individuals with low perceived ability withhold effort and disengage from a task more readily as difficulty increases (44,45). Moreover, individuals with low perceived ability appear to experience greater effort than those with high perceived ability at a given level of task difficulty when task difficulty is relatively low (44). From this perspective, participants in the control group would not be expected to alter their perceived ability; thus, the perception of effort and endurance performance would remain similar, as was the case. By extension, it is noteworthy that no statistical difference in RPE was evident between groups at 0% isotime. Furthermore, mood and motivation were also not statistically different between groups before the TTE test. This suggests that it was the effect of motivational self-talk during the task rather than an enhanced sense of perceived ability, mood, or motivation on entering the test that led to the 18% improvement in time to exhaustion.

We also recorded HR and facial EMG amplitude during high-intensity cycling exercise, along with blood lactate concentration 3 min after exhaustion. HR and blood lactate at exhaustion were not significantly different between groups. Similarly, self-talk did not have a significant effect on HR at isotime. Although it would be inappropriate to declare that all unmeasured physiological parameters were also similar between groups, these data limit the possibility that the increase in time to exhaustion we observed in the self-talk group can be explained by traditional musculoenergetic and cardiovascular mechanisms (1,24). In addition, models of pacing such as the afferent feedback model (2) and the central governor model (35) have been recently proposed to determine the basis of endurance performance. These models are specifically founded on the premise that the brain limits performance according to the physiological condition of the body. However, a purely psychological strategy such as self-talk is unlikely to modify afferent feedback from the locomotor muscles (2) or alter any threat to physiological homeostasis (35). Therefore, these models are also unable to fully account for why our psychological intervention was able to reduce RPE and enhance endurance performance.

Previously, facial EMG amplitude has been shown to correlate with RPE during weightlifting (10) and to differentiate between two different exercise intensities during cycling to exhaustion (11). In our study, facial EMG amplitude, like RPE, increased significantly in both groups during the TTE test. Interestingly, however, facial EMG amplitude at isotime was not significantly affected by motivational self-talk, despite its significant effect on RPE. A possible explanation for this discrepancy is that the increase in facial EMG amplitude that occurs during high-intensity cycling exercise reflects motor irradiation (11). Under these circumstances, the spreading of activation in cortical and subcortical regions stimulates not only the muscles involved in the task but also task-irrelevant muscles (21), such as the facial muscles (10). Alterations in facial EMG activity may therefore not be expected to occur when differences in the perception of effort result from cognitive factors such as motivational self-talk. This is supported by the fact that cognitive effort and facial EMG amplitude are not consistently associated in the psychophysiology literature (8,39) and explains why facial EMG differences were not discernible between groups despite the clear change in RPE in the self-talk group.

To contextualize our findings, potentially limiting aspects of the study should also be acknowledged. For example, a TTE test is suggested to be less ecologically valid than, for example, a time trial, because it excludes pacing. However, given that the present study aimed to establish the effects of motivational self-talk on the perception of effort and task termination, as opposed to pacing, the influence of a self-paced power output such as that during a time trial would have made it difficult to clearly establish the effect of the intervention on perceptual and physiological responses. Moreover, some authors think that the large variability in TTE tests can make it difficult to detect real changes in performance (23). However, it has been demonstrated that TTE tests and time trial tests have similar sensitivity to changes in endurance (3). This is because despite the variability in these tests, performance enhancement also tends to be much greater (20), thus compensating for this variability. Put another way, the signal to noise ratio remains similar to that of a time trial. The present study also did not include a familiarization visit. It is acknowledged that this could have led

to practice effects across visits 2 and 3. Nonetheless, the lack of an increase in performance in our control group during visit 3 somewhat argues against this.

During the manipulation check, 10 of the 12 participants in the control group reported using some self-talk during their TTE test. This, however, corresponds to previous findings (14) whereby 95% of a sample of 164 exercisers reported the use of self-talk during their workout. In this regard, given the prevalent nature of self-talk, an inherent issue associated with control groups is whether it is realistic to eliminate self-talk entirely. Moreover, alternative approaches for the control group are not without their own issues; for example, the introduction of potential confounds via distracter type tasks. Nevertheless, as performance was only enhanced in the self-talk group, this signifies that it may be practiced and specifically structured motivational self-talk (18) that provides the key to endurance performance enhancement as opposed to the use of self-talk *per se*. Practically, this suggests that individuals who take part in endurance exercise should be trained in the use of structured and personalized motivational self-talk.

Because of the problematic nature of control groups in self-talk research, the possibility that our findings could be attributable to a placebo effect cannot be entirely eliminated. However, a placebo-driven 18% improvement in time to exhaustion might be regarded as substantial. This is supported by a notably lesser change in performance of approximately 6.5% in the placebo group of a placebo controlled study using a comparable mode, intensity, and sample population as ours (15). Similarly, it is possible that the additional 30 min that the self-talk group spent with the experimenter during stage 1 of the self-talk workbook procedure could have provoked either experimenter effects or experimenter bias. Once more, however, an 18% improvement in response to either of these would appear extremely large.

In light of our findings, it is important that future research examines the effects of motivational self-talk on the perception of effort and time trial performance so as these findings can be extended more specifically to competition. In addition, to make these findings more pertinent to individuals of a superior training standard to our participants, similar investigations should be performed on elite and subelite athletic

cohorts if possible. Moreover, owing to our proposed link with perceived ability, the interplay between motivational self-talk, perception of effort, and perceived ability should be empirically clarified. Likewise, it would be interesting to determine whether the novel theoretical framework provided by the psychobiological model of endurance performance extends to other psychological strategies such as imagery and goal setting. Finally, in recognition of the psychobiological link between motivational self-talk and endurance performance, it is important that the neural structures that are activated by motivational self-talk are identified. This would provide a greater understanding of the psychobiological connections between motivational self-talk, the perception of effort and endurance performance.

In summary, our theoretically grounded findings are the first to experimentally demonstrate that the isolated use of motivational self-talk is an effective strategy for endurance performance enhancement. In addition, this is the first study to reveal that this enhancement is associated with a significant reduction in the perception of effort. The latter finding has several implications. First, this strongly supports the psychobiological model of endurance performance, which proposes that the point recognized as exhaustion is determined by the conscious decision to terminate endurance exercise. Second, this supports the perspective that any intervention that affects the perception of effort will affect endurance performance. Finally, this illustrates that psychobiological interventions designed to specifically target favorable changes in the perception of effort are of benefit to endurance performance and should be extensively investigated in the context of competitive preparation for endurance athletes.

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