Original research papers

EFFECTS OF VERBAL FEEDBACK ON MOVEMENT EFFICIENCY DURING SWIMMING ERGOMETRY

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Abstract

Introduction. The aim of the study was to ascertain the physiological effects of verbal feedback on changes in the movement efficiency of a dry-land swimming ergometry task (butterfly stroke). ***Material and methods.*** The study involved 100 healthy and physically active males (1st year university students majoring in physical education) that were untrained in swimming (19.56 ± 1.32 years of age, 181.23 ± 4.35 cm in height, and 70.54 ± 8.6 kg in weight). The sample was randomised into two groups (control and experimental). In the first trial, both groups executed the butterfly stroke on a Weba Sport swim ergometer with no augmented feedback. In a second trial, the experimental group was provided with verbal cues relating kinesthetic information on task execution. Trial duration was 10 min, with the first 5 min devoted to the swimming task and the remaining 5 min serving as a cool-down. Variables under consideration included physiological cost, rate of recovery, heart rate recovery, estimated recovery time, and work output. ***Results.*** No improvement in the variables related to the physiological cost was observed in the verbal feedback condition although a significant increase in work output was observed in the experimental group ($p < 0.05$). ***Conclusions.*** An improvement in work output without modulating the physiological cost of work suggests that appropriately prepared verbal cues may enhance performance in a swimming ergometry task.

Key words: swimming, verbal information, kinesthetic information, physiological cost, work output

Introduction

The optimisation of exercise technique by enhancing movement efficiency has been the subject of extensive scientific research over a number of years. New research directions have emerged as investigators search for ways to enhance motor performance and mechanical economy [1]. This body of research is grounded in the concept that humans continually update motor patterns as a result of numerous forms of feedback [2]. Among various sources of feedback, intrinsic feedback involves exteroceptive or proprioceptive information that is processed to adjust movement as well as compare task execution with a priori motor imagery [3]. This feedback is provided by the neuromuscular sense organs, including the vestibular apparatus which aids balance and spatial orientation, muscle spindles that detect changes in muscle length and velocity, and the Golgi tendon organs which sense changes in muscle tension. Another source of feedback is termed as extrinsic and acquired from external stimuli such as verbal or visual cues. Increased experience with intrinsic and extrinsic feedback allows for enhanced movement execution in ever more complex movement structures [2].

A key benefit in the optimisation of a movement structure is that it allows the performer to complete a movement task with ever decreasing energy expenditure [4]. The increasingly efficient execution of a movement at minimised physiological cost can thus be treated as an example of movement efficiency. This principle generally governs the underlying concept of technique. In sports that are based on the continuous repetition of a task (e.g. swimming), long-term and continuous practice reduces the homeostatic disturbance evoked by such movement and also automates its execution [5]. This in effect improves force production and movement precision with a concomitant reduction in energy expenditure resulting in improved performance [6].

While enhanced movement efficiency is an inherent goal of any form of repeated practice or training, it can be significantly encumbered if a task is performed in an abnormal environment or modulated by external conditions, as is the case with swimming. For example, both perception and sensory information (intrinsic feedback) can be disturbed during swimming by not only the inherent physical characteristics of water (e.g., temperature, pressure, and density) but also the introduction of new forces (e.g., buoyancy and drag) [7]. In such conditions, it has been suggested that intrinsic feedback could be supplemented with extrinsic feedback to strengthen the kinesthetic feedback loops [8]. The introduction of such kinesthetic information could provide additional complementary knowledge on joint position and movement, muscle force production, or body position [9].

One way of optimising movement efficiency is by enhancing muscle tension control, which can assist the muscle relaxation cycle when the muscle is no longer used [10]. Muscle tension also plays an important role in the kinesthetic differentiation of movement or the ability to determine the kinematic, spatial, and temporal properties of an executed movement while pairing this data with previously stored motor programmes [11]. Improved kinesthetic differentiation has been found to enhance sensory processing and allow for more precise and efficient movement execution [12]. Hence, methods that may deliver effective forms of feedback on kinesthetic sensation may result in improved movement efficiency.

Many swim training programmes involve a dry-land component executed on a swim ergometer [13]. Besides providing valuable kinematic data, dry-land ergometer swimming has been found to enhance swim stroke execution and positively influence stroke movement efficiency [14]. Improved efficiency can reduce the physiological cost of swimming and improve competitive swimming performance [15]. Therefore, the addition of kinesthetic-based feedback can potentially have several positive outcomes during swimming ergometry via improvements in execution efficiency.

Study aim and hypothesis

The purpose of study was to determine whether verbal feedback can reduce the physiological cost of swimming ergometry. It was hypothesised that verbal cues relating kinesthetic information could improve movement efficiency.

Material and methods

Subjects

One hundred healthy and physically active males were recruited (age = 19.56 ± 1.32 years, height = 181.23 ± 4.35 cm, mass = 70.54 ± 8.6 kg). All were 1st year university students majoring in physical education and with no competitive experience in swimming (untrained persons with normal swimming experience). The subjects shared a similar fitness profile, practising 2 h of sport per week. Written informed consent to participate in the study was obtained after the procedures were fully explained. A randomised controlled trial design was chosen, in which the sample was divided into a control and experimental group. Student's t testing revealed no differences between the two groups.

Procedure

The study design was approved by the institutional ethics committee, and all procedures were performed in accordance with the Declaration of Helsinki. Two dry-land swimming trials of the butterfly stroke using a 5-kg load were executed. A metronome was used to maintain pace at one stroke per 2.5 s, and each stroke was treated as a return to the initial position with the arms stretched over the head and in front of the participant.

The participants were familiarised with the device prior to study outset. In the first trial (pre-test), both groups performed the task with no verbal feedback. In the second trial (post-test), verbal feedback was provided to the experimental group by one of the study authors. The control group did not receive any feedback and performed the trial exactly as in the pre-test. In order to minimise the effects of fatigue, the trials were separated by a 48-hour interval. The trials were performed at the same time of day in an indoor facility with controlled environmental conditions (temperature, humidity, and air movement). Trial duration in each case was 10 min, where the first 5 min involved performing continuous butterfly strokes and the remaining 5 min was provided for a cool-down.

Verbal feedback

The experimental condition was based on verbal feedback transmitting kinesthetic information on butterfly technique and treated as the independent variable. A pilot study had been previously conducted to design and verify the applied intervention protocol for the experimental group. The goal was to develop verbal feedback suitable to deliver information on kinesthetic sensation. The pilot study involved 20 males not recruited in the experiment proper. Verbal feedback was based on the criteria for efficient didactic communication (syntax, semantics, and pragmatics). Syntax was used to deconstruct the movement into a sequence of motor activities so that the information would be ordered and follow the temporal sequence of execution. Semantics was applied to provide a uniform language understood by all parties and, most importantly, provide information that is fully comprehensible for the person performing the movement. We used pragmatics in reference to the language that would best explain task execution [16], understanding that feedback must be succinct in order to be effective due to the effects of short-term information retention [17]. A series of trials were designed to determine a protocol that included the most needed information and the most effective delivery format to minimise the physiological cost of the ergometer task. The final list included ten statements verbally communicated by one experimenter once in sequential order. If an error was made, ongoing feedback was provided with the most appropriate statement. The statements were as follows:

1. Lie comfortably on the bench so that no tension is felt in any part of the body.
2. Comfortably hold onto the handles so that the fingertips touch the edge.
3. Keep the elbows slightly bent.
4. Keep the hands slightly flexed.
5. Swim with the arms at a constant pace.
6. Squeeze the handles using the entire surface of the hand.
7. Smoothly perform the movements (do not jerk the arms).
8. Tense the muscles when pulling on the handles but relax during the recovery phase.
9. Tense the buttock and back muscles when pulling with the arms.
10. Pull the arms until they reach the hip.

Test equipment

A Weba Sport swim ergometer (Weba Sport und Med. Artikel GmbH, Germany) was used in all procedures (Fig. 1). The apparatus consisted of a bench with two independent handles and a computer that measured work output per stroke (J). Heart rate – HR (beat/min) – was continually recorded using a heart rate monitor (Polar Electro RS400, Finland).

Variables

Movement efficiency was determined in the study by establishing work output (J) per stroke and calculating four correlates of physiological cost: absolute physiological cost (PC), rate of recovery (ROR), heart rate recovery (HRR) (∑HRbeats), and estimated recovery time (ERT). These variables have been pre-

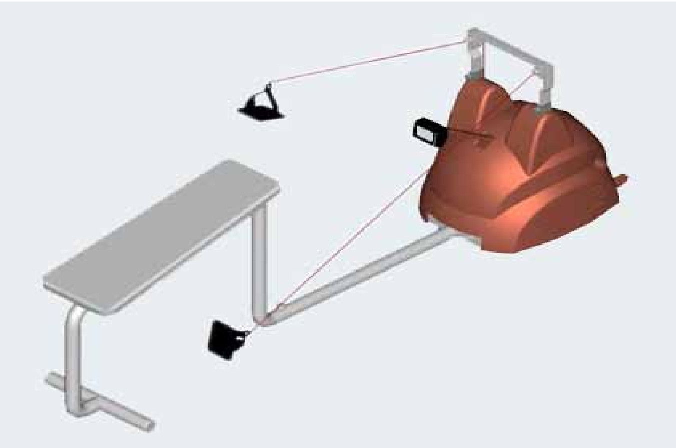

Figure 1. The Weba Sport swim ergometer (Weba Sport und Med. Artikel GmbH, Germany)

viously used in the literature as reliable and valid predictors of physiological cost [18, 19, 20].

PC (∑HRbeats) was treated as the sum of total heart beats in the 5-min butterfly task and 5-min cool-down using the following formula PC = ∑HR during task execution + ∑HR during recovery – (*t* task + *t* recovery) × HRrest, where:

- ∑HR task – number of heart beats during swimming task,
- ∑HR recovery – number of heart beats during cool-down (i.e., until heart rate returned to resting value based on ERT),
- *t* effort – duration of main task (5 min),
- *t* recovery – duration of cool-down needed for HR to return to resting value (min),
- HRrest – resting heart rate [18].

ROR (%) after the completion of the butterfly task was determined using the formula ROR = (*t* 2 – t *3*) / (t *2* – t *1*) × 100%, in which the higher the obtained value, the more effective the recovery process, where:

- *t* 1 – resting heart rate,
- *t* 2 – maximum heart rate,
- *t* 3 – heart rate at the end of cool-down (5 min) [19].

To better illustrate the changes during the cool-down, HRR (∑HRbeats) was also calculated as the sum of heart beats above HRrest using the formula HRR = ∑ HR recovery – *t* recovery x HRrest, where:

- ∑ HR recovery – total heart beats during the recovery phase,
- *t* recovery – duration of recovery (min) needed for HR to return to resting values (if HR did not return to resting values then ERT was used),
- HRrest – resting heart rate [20].

ERT (min) was the predicted time needed for heart rate to return to resting levels (HRrest) based on the decrease of HR during the 5-min cool-down. Assuming a linear function, the ERT for HRrest was extrapolated using $y = ax + b$, where:

- y – heart rate (value of the function),
- x – time (argument of the function),
- a – slope coefficient,
- b – displacement [20].

Statistical analyses

Basic descriptive statistics were calculated. Differences in the mean values of the analysed variables between groups and trials were determined using two-way analysis of variance (MANOVA) [21]. Levene's test was applied to confirm the homogeneity of variance. The Duncan test was used for post-hoc comparisons. Statistical significance was set at $p \leq 0.05$ for all procedures. Data were reported as means and standard deviations and provided in table format.

Results

Table 1 presents the mean changes in work output and the movement efficiency variables at post- and pre-test for both groups. The differences in pre- and post-test PC were significant only in the control group ($p < 0.05$). Furthermore, the change of direction in PC was different between the two groups, in that post-test PC decreased in the control group by 53.90 ∑HRbeats but increased in the experimental group by 5.00 ∑HRbeats. ROR decreased in both groups at post-test but only the decrease in the control group was significant (by 5.95%, $p < 0.05$). Similarly, while a similar direction of change was observed in both groups between pre- and post-test HRR, only the decrease in the control group was significant (by 52.91 ∑HRbeats, $p < 0.05$) compared with the decrease in the experimental group (by 22.50 ∑HRbeats). ERT significantly decreased in both groups ($p < 0.05$) although the decrease was greater in the experimental group by 3.00 min compared with 2.00 min in the control group. A significant post-test increase ($p < 0.05$) in work output per stroke was observed in the experimental group by 19.4 J whereas the increase in the control group was only 0.79 J and not significant. The post-test difference between the two groups was also significant.

Table 1. Pre- and post-test movement efficiency during swimming ergometry for both groups

Variables	Control group			Experimental group		
	Pre-test	Post-test	Δ	Pre-test	Post-test	Δ
Absolute physiological cost [∑HRbeats]	497.40 ± 213.40	443.5 ± 188.6*	−53.90	466.40 ± 236.60	471.4 ± 186.10	5.00
Rate of recovery [%]	63.43 ± 18.09	69.38 ± 15.57*	5.95	67.59 ± 19.72	71.88 ± 15.35	4.29
Heart rate recovery [∑HRbeats]	269.35 ± 180.70	216.44 ± 136.6*	−52.91	238.20 ± 168.20	215.70 ± 116.30	−22.50
Estimated recovery time [min]	12.00 ± 7.43	10.00 ± 4.73*	−2.00	12.00± 8.06	9.00 ± 3.39*	−3.00
Work output per stroke [J]	59.73 ± 15.7	60.52 ± 15.9	0.79	65.18 ± 23.8	84.22 ± 17.8*	19.04

* p ≤ 0.05 vs. pre-test measure; a negative delta change denotes a decrease.

Discussion

Dry-land training on a swim ergometer has been found to improve swimming performance [22]. During the training macrocycle, swimmers perform approximately 300 hours of dry-land training per year, with 60% of this time devoted to strength and conditioning exercises [13, 14, 15]. Hence, the search for methods that may optimise performance in these settings is particularly warranted. In the present study, the underlying goal was to determine whether verbal feedback can reduce the physiological cost of swimming ergometry. The stated hypothesis was only partially confirmed in that while physiological cost and other related variables did not change after verbal feedback was introduced, an increase in work output at a similar physiological cost suggests that appropriately prepared verbal cues can lead to enhanced outcomes.

Feedback plays a significant role in the development of motor skills. The literature is agreed that verbal feedback is an important element in the improvement of movement-based activities and that it may be the most effective form of feedback [23]. It can augment intrinsic feedback by supplementing it with information on joint displacement, force production, or body position. Surprisingly, few studies have addressed the relationship between verbal feedback and movement efficiency. Existing research in this area has investigated the effects of the quantity and frequency of verbal feedback on the optimisation of movement [24, 25]. All of the cited works concluded that verbal feedback had a strong, positive influence on motor behaviour. In a study by Zatoń [16], a link between movement efficiency during swimming and verbal feedback was first posited. Later, Zatoń and Szczepan [26] concluded that adequately prepared verbal feedback could immediately result in lowered physiological cost as evidenced by the increase in a stroke efficiency index. Many studies have suggested that the increase in movement efficiency is the result of improved kinesthetic sensitivity or the ability to differentiate muscle tension [27, 28]. Zatoń and Klarowicz [29] pointed out the significance of verbal feedback in allowing a learner to consciously accept feedback from different receptors. The authors concluded that verbal feedback can improve the reception of extrinsic and intrinsic feedback and therefore the execution of a water-based task. From a purely physiological standpoint, an improvement in the mechanisms responsible for movement regulation can lower the energy cost of swimming effort and therefore improve movement efficiency [30]. In the context of swimming, it has been suggested that acquisition of the purported "feel of the water" or the influence of various water-based stimuli, their interpretation, and later adjustment can help improve movement execution [31]. Hence, the application of verbal feedback that involves a kinesthetic component, as in the present study, could have modified motor behaviour by optimising muscle tension and therefore enhancing movement efficiency. Future research should confirm the effects of such verbal feedback by measuring muscle tension.

Worthy of mention is that feedback needs to be adequately prepared in order effectuate the retention of information from various sources. In the case of verbal feedback, it is important that such information follow certain pre-established criteria for effective communication including the consideration of semantics, pragmatics, and syntax [16]. Respecting such requirements, we introduced a series of clear and concise instructions with minimal verbosity that could improve movement efficiency during swimming ergometry. Instructions delivered in this context are particularly important as the communication and demonstration of effective technique is difficult during in-water training. As could be observed in the present study, carefully prepared verbal feedback conveying kinesthetic information can influence power/force production, possibly by correcting flaws in stroke execution. This form of training warrants additional research particularly in comparison with other dry-land training modalities.

The present study has certain limitations that require caution when interpreting the results. No retention testing was performed to study the long-term effects of the verbal feedback provided, such as finding the time for work output to decrease after the verbal feedback intervention. More importantly, the present sample involved university students untrained in swimming. The results could have been cross-validated with a sample of trained or elite-level swimmers that would have allowed for more in-depth group comparisons particularly if females had been recruited. Furthermore, more practical conclusions could have been drawn if the study had included a longer training intervention using the developed verbal feedback cues and not comparisons of two short-duration trials.

Conclusions

While the verbal feedback provided did not improve the physiological cost of butterfly ergometry, an improvement was observed in work output per stroke cycle. This increase in work output with no change in physiological cost suggests that appropriately prepared verbal cues may enhance efficiency in swimming ergometry performance.

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