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DOI: https://doi.org/10.1016/j.smhs.2023.08.001

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ZORA URL: https://doi.org/10.5167/uzh-253851
Journal Article
Published Version

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Originally published at:
Mirmoezzi, Masoud; Sayyah, Mansour; Taheri, Morteza; Irandoust, Khadijeh; Sangari, Mandana; Mirakhori, Fatemeh; Seghatoleslami, Ali; Hill, Lee; Weiss, Katja; Knechtle, Beat; Ghram, Amine (2024). Effect of self-modeling and self-controlled feedback on the performance of professional swimmers and waterpolo players. Sports Medicine and Health Science, 6(2):167-172.
DOI: https://doi.org/10.1016/j.smhs.2023.08.001

ARTICLE IN PRESS

Sports Medicine and Health Science xxx (xxxx) xxx

Contents lists available at ScienceDirect

Sports Medicine and Health Science

journal homepage: www.keaipublishing.com/smhs

Effect of self-modeling and self-controlled feedback on the performance of professional swimmers and waterpolo players

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ARTICLE INFO

Keywords:
Feedback
Self-control
Self-modeling
Swimming
Water polo

ABSTRACT

Self-modeling (SM) and self-control (SC) feedback can be presented as two solutions for learning improvement. Therefore, the aim of the present study was to investigate the effects of SM and SC feedback on 100-m freestyle performance of professional swimmers and waterpolo players. 25 elite male swimmers and waterpolo players, were randomly assigned to four groups: swimmer group with SM, swimmer group with SM and SC feedback, waterpolo players group with SM, and waterpolo players group with SM and SC feedback. 100-m freestyle times and performance were recorded. SM and SC feedback for the participants were utilized at the acquisition stage. The device used included a Lenovo B570 laptop and an Exilim ZR200 canon camcorder. SM and SC feedback presented to the swimmers and waterpolo players led to improved speed and results, and the effect of presenting SM with SC feedback to swimmers had better results. In conclusion, the present study indicates that SC modeling of watching video is a suitable method for professional swimmers. Water polo trainers can also use SM and SC feedback to enhance their players' swimming technique.

1. Introduction

The primary focus of sport science is to maximize training outcomes and provide a improved framework for learning and attaining top performance.[1,2] Learning through observation or modelling is one of the most common techniques used in motor skills training.[3–5] The discovery of the mirror neuron system in the brain has elicited much excitement and research regarding the possibility that specific neural mechanisms provide the foundation for learning through observation.[6–8]

One of the most effective methods of learning is the self-modeling (SM) method, allows learners to see themselves performing target behavior.[9] Researchers have suggested using a model that makes the observer find the maximum convergence with their model, having the most significant impact on learning, self-efficacy beliefs, and the

Abbreviations: BFP, body fat percentage; BMI, body mass index; SC, self-control; SM, Self-modeling.

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https://doi.org/10.1016/j.smhs.2023.08.001
Received 15 October 2022; Received in revised form 20 July 2023; Accepted 28 August 2023
Available online xxxx
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Please cite this article as: Mirmoezzi M et al., Effect of self-modeling and self-controlled feedback on the performance of professional swimmers and waterpolo players, Sports Medicine and Health Science, https://doi.org/10.1016/j.smhs.2023.08.001

development of pervasive psychological traits and believe that observing SM can be most similar to the models.[10,11] In the self-observation technique, the learner observes his previous performance without interfering with the film.[8] Dowrick argued that when the observer studies his model, he will more effectively process the information and use modelling technique strategies.[10] Charlop-Christie et al. showed that video modelling was more cost-effective than a live model and required less time.[9] The results of the studies conducted by Chiricowsky and Wulf[12] and Menickelli[1] showed that the variable that affected learning through physical exercise and, similarly to observational learning, was the terminal augmented feedback. These studies have shown the effectiveness of various modes of augmented feedback, among which self-controlled feedback may produce superior outcomes.[1,12,13] Wulf et al. showed that participants, who decided on their receiving time, had better learning in the retention phase,[3] but its role in interacting with observational learning still needs to be investigated.

Swimming and water polo are aquatic sports that require specific training for speed, endurance and proper execution of techniques.[14] Swimming is a sport where passing the specified distance in the shortest possible time is considered crucial for optimal performance.[14] On the other hand, water polo is a sport that mixes aspects of swimming (speed and endurance) with a ball game where the objective is to outscore the opposing team.[15] However, because these exercises are performed in the water, it is difficult to guide swimmers properly, and coaches are always looking for practical and effective ways to transfer information and relevant feedback to their athletes in the best possible way.[14]

Advances in science and technology have allowed trainers and coaches to measure almost every aspect of training, enabling almost instantaneous feedback. This includes using video feedback through video recording,[16] accelerometry,[17] three-dimensional modelling,[18] and wireless inertial sensors[19] which can assist with technique correction.[20]

Since speed plays a decisive role in swimming and water polo, and the requirement for speed in a fluid with about 12 times more resistance than air is to have a suitable technique to minimize the water drag force and increase the swimmer's thrust force. With this default, achieving the desired technique even for professional swimmers is correct implementation of swimming techniques and better learning.[14],[15] Given that cognitive processes are involved in observation and physical training, providing feedback and model observation can significantly impact the effectiveness of observational learning (*i.e.,* thereby leading to better and more sustainable learning).[21] On the other hand, feedback that provides information about the execution model to the observer plays a vital role in observational learning processes. Studies have investigated the effect of SM on beginners but in these studies athletes have been novices and its effect on skilled people is unclear.[11,22] Some studies have examined individual sports and the relationship between SM and SC feedback between individual and team sports have not been fully explored. And in a way, open versus closed skill training;[22,23] and so far no research has been conducted on skilled athletes in which learners benefit from SC feedback.

Therefore, we were looking for answers to the following questions: Can combining different feedback and modeling techniques lead to error correction and increase the learning and the performance of swimmers and waterpolo players?

The purpose of the study was to investigate the effect of SM and SC feedback on 100-m freestyle performance of professional swimmers and waterpolo players. We hypothesized that SM and SC feedback will improve performance in team and individual aquatic sports.

2. Method

2.1. Ethical approval

The research was approved by the local ethics committee Imam Khomeini International University (ref. no. 17628), which was performed in accordance to the seventh and current revision (World Medical Association, 2014) of the Declaration of Helsinki. In order to adhere to the research ethics, all subjects were required to provide their informed consent.

2.2. Participants

The present study was a pretest-posttest control group experimental design with four groups. Twenty-five male swimmers (Mean age [M] = 19.5 years, $SD = 1.3$) with 7–10 years practice experience ($M = 8.4$, $SD = 1.2$) participated to the present study (Highly trained, regionals and national level competitors; Qazvin province, Iran). Sample size was established a priori (considering the performance variable) by adopting an effect size = 0.80 an $\alpha = 0.05$ and a $\beta = 0.80$. For 25 subjects, the calculated sample power was 0.87. As inclusion criteria: (i) Be affiliated to an swimming federation; (ii) Average weekly training is at least 20 km; (iii) Do not use any type of substance that could exert any type of ergogenic effect (i.e. food supplements; use of illegal drugs for performance enhancement as anabolic steroids) (iiii) None of the swimmers suffered major injury or sickness preventing them from training for 12 sessions. Swimmers dry-land training daily routine were composed on an average of 50% warm-up and stretching exercise, 25% submaximal strength exercise, and 25% maximal strength exercise.The swimmers practiced swimming 5–7 km in each training session. Fig. 1 shows the CONSORT flowchart of the study. In order to adhere to the research ethics, all were required to provide their informed consent. They could be excluded from the study at any stage. All participants provided informed consent after having been presented the benefits and risks of their participation in the present study.

Anthropometric indices include body height, body mass, body mass index (BMI), body fat percentage (BFP), shoulder width, arm span, palm width, the circumference of the chest, waist, hip, wrist and contracted arm, upper and lower body length, length of the foot, hand and palm were measured. BFP, BMI and body mass was measured using InBody 270 (InBody, South Korea) and body measurements using the Ghamatpooyan® anthropometric Kit (Ghamatpooyan, Tehran, Iran). These measurements were taken on the subject's right side. Swimmers were asked to observe pre-workout activities (light exercise, eating light meals) and attending regular during the workout.

2.3. Procedure and tasks

Swimming record times and strokes were used to evaluate the swimmers' specific performance in the 100 m freestyle. Thus, after a warm-up (The control warm-up included a typical race-pace set: 4 × 25 m), the time was measured using a stopwatch q&q digital stopwatch, model SG - HS47, function - 1/100 s, Japan Quartz Movement). The following formula: [(number of strokes in 100 m) ∕ (swim time in seconds) × 100] was used to calculate the frequency of the strokes.[14] SF is defined as the number of full stroke cycles performed within period.The main focus is to enhance a unit of time (strokes.seconds^{-1}) or Hertz (Hz). In order to eliminate the kinematic variables affecting swimming performance, all the swimmers started with a push start from the pool wall. To eliminate any potential interference, each swimmers performance was measured three times during the week, and the best record and strokes frequency were recorded as a pre-test. The swimmers then performed the protocol presented in Table 1 by group separately, resting 48 h after 12 sessions, re-recording 3 times a week, and the best record and strokes frequency recorded as post-test. All the evaluations were done at 5:00 p.m. (regular training time). During these four weeks, all participants did not have specific swimming exercises and only did aerobic endurance training (en1) to prevent aerobic capacity decline and physical fitness. The follow-up training program started after detraining from the previous swimming year (transition phase). The test was conducted in the off-season.

$$[(\text{number of strokes in 100 m}) / (\text{swim time in seconds}) \times 100] \text{ Formula} \quad (1)$$

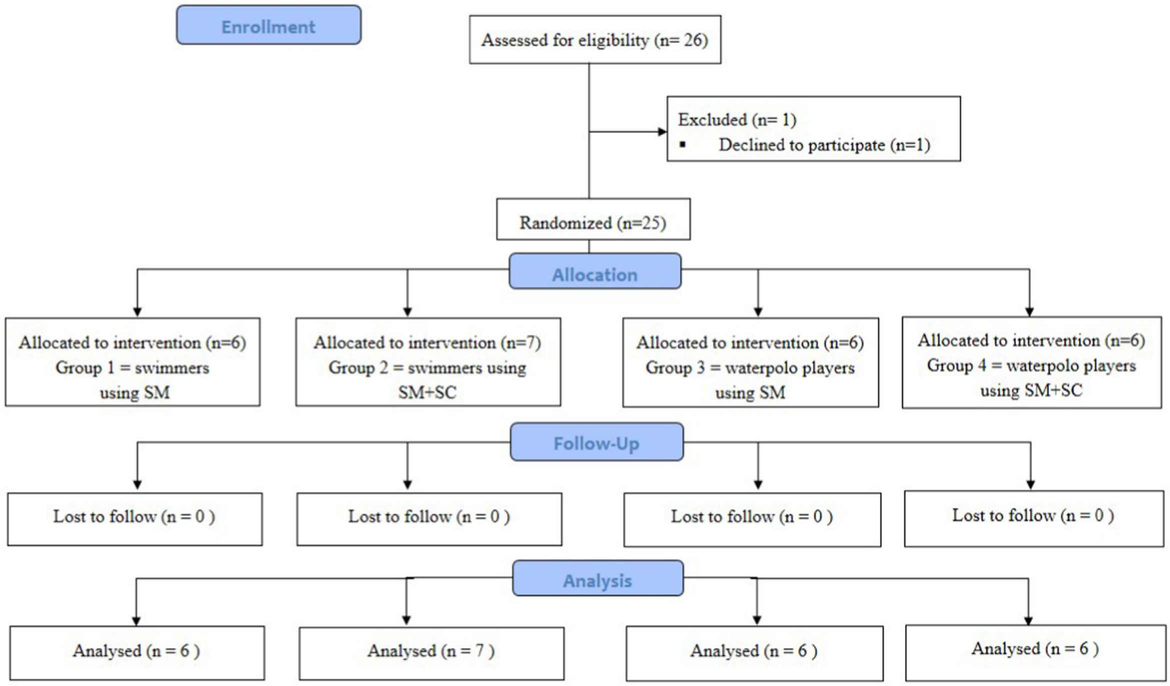

Fig. 1. CONSORT flow diagram of the four groups. SM: Self-Modeling, SC: Self-Control.

Table 1
The exercise protocol.

Warm-up	Frequency	Sessions	Rest
Dry land warm-up (5 min), freestyle Easy 10 min at 120–140 beats per minute	3 session per week for 4 weeks on even days	5 × 100 m freestyle and record	10 min rest between efforts

Participants were randomly assigned into four groups: Group 1 = swimmers using SM ($n = 6$), Group 2 = swimmers using SM+SC ($n = 7$), Group 3 = waterpolo playersusing SM ($n = 6$), Group 4 = waterpolo players using SM+SC ($n = 6$). Applying the independent variable in 12 training sessions, two groups in the swim and the water polo groups only provided SM (a swimmer's video), and the others swim and water polo groups in addition to SM requested SC feedback. Participants in each group were asked to be in their group. In the SM groups, the participants' swimming was filmed and displayed immediately for the participants. In the SM and SC feedback groups, the participants' swimming and after 10 min rest, the coach with a coaching certificate from Swimming Federation of Iran (IRSF) provided and controlled the SC feedback individually for each subject. These procedures were performed for all participants. The device used included a Lenovo B570 laptop and an Exilim ZR200 canon camcorder.

2.4. Statistical analysis

The statistical analysis was performed using the SPSS v21.0 software (SPSS Inc., Chicago, IL). Data are presented as mean ± *SD* in the table and the text. The Shapiro–Wilk test was use to confirm normality of the data. Therefore, parametric methods were used for data analysis. The data were analyzed using analysis of covariance (ANCOVA) test to control for pre-existing differences on the dependent variable. Post-hoc tests of Bonferroni were also used for comparing the means. Significant difference was set at $p \leq 0.05$.

3. Results

The results of the one-way ANOVA test before exercise showed no significant differences between any of the anthropometric indices involved in swimmers' speed ($p < 0.05$). Table 2 shows the individual characteristics and the anthropometric indices of the swimmers.

The swimmers' record and strokes frequency in pre- and post-test are given in Table 3. The post-test record and strokes frequency were improved in the four groups (Table 3).

Covariance analysis showed that there were significant difference in record ($F_{[3,\ 20]} = 49.24, p = 0.014, \eta^2 = 0.56$) and strokes frequency ($F_{[3,\ 20]} = 51.05,\ p = 0.006,\ \eta^2 = 0.62$). Swimmers using SM were significantly lower in record ($p = 0.014$) and stroke frequency ($p < 0.001$) than

Table 2
Anthropometric indices of semi-professional swimmers and waterpolo players in the self-modeling and self-controlled feedback in the 4 groups (mean).

Groups	Group 1	Group 2	Group 3	Group 4
Age (years)	19.55	20.14	18.98	21.01
Height (cm)	176.12	178.29	179.01	175.87
Weight (kg)	74.11	75.41	79.05	73.88
BMI (kg.m^{-1})	23.89	23.72	24.67	23.89
BFP (%)	16.97	16.90	17.77	17.30
Shoulder width (cm)	58.58	56.41	60.64	59.21
Arm span (cm)	177.15	179.85	180.11	177.14
Palm width (cm)	12.23	11.5	10.99	11.78
Chest circumference (cm)	32.15	33.18	31.88	30.99
Waist circumference (cm)	79.45	78.14	80.15	81.25
Hip circumference (cm)	30.14	29.75	31.15	28.78
Wrist circumference (cm)	23.5	23.78	21.1	24.01
Contracted Arm (cm)	27.15	27.27	29.12	26.48
Upper body length (cm)	83.14	85.74	88.75	86.45
Lower body length (cm)	110.15	115.14	117.55	112.14
Foot length (cm)	28.11	27.11	29.44	26.99
Hand length (cm)	70.15	71.29	75.01	73.74
Palm length (cm)	20.15	19.48	21.12	20.77

BMI: Body Mass Index, BFP: Body Fat Percentage.
Abbreviations: Self-modeling: (SM); self-control (SC).
Group 1 = swimmers using SM, Group 2 = swimmers using SM+SC, Group 3 = waterpolo players using SM, Group 4 = waterpolo players using SM+SC.

Table 3
Record and frequency of swimmers' strokes in the 4 groups (mean ± *SD*).

Groups	Record (s)		Stroke frequency (number)	
	Pre-test	Post-test	Pre-test	Post-test
Group 1	69.93 ± 1.84	67.13 ± 2.08	70.25 ± 3.14	64.19 ± 3.01
Group 2	69.57 ± 1.58	65.09 ± 1.15	67.12 ± 1.21	62.23 ± 2.71
Group 3	71.33 ± 2.72	70.36 ± 2.14	75.23 ± 2.42	70.28 ± 3.39
Group 4	72.51 ± 2.68	69.51 ± 2.43	71.85 ± 3.78	66.29 ± 2.35

SM: Self-Modeling, SC: Self-Control.
Group 1 = swimmers using SM, Group 2 = swimmers using SM+SC, Group 3 = waterpolo players using SM, Group 4 = waterpolo players using SM+SC.

waterpolo players using SM. In addition, record and stroke frequency were significantly lower in swimmers using SM+SC than swimmers using SM ($p = 0.042$ and $p = 0.034$, respectively), waterpolo players using SM ($p < 0.001$ and $p < 0.001$, respectively), and waterpolo players using SM+SC ($p < 0.001$ and $p < 0.001$, respectively). In addition, there was a significant difference between waterpolo players using SM and waterpolo players using SM+SC in strokes frequency ($p < 0.001$) (Fig. 2). We had improved record and performance in swimmers and waterpolo players using SM and SM+SC (Fig. 2).

4. Discussion

The present study investigated the effect of SM and SC feedback on 100-m freestyle performance of professional swimmers and waterpolo players. The main finding of this study showed that SM and SC feedback have significant effect on 100 m freestyle performance of professional swimmers and waterpolo players. Swimmers using SM were significantly lower in record and stroke frequency than waterpolo players using SM. In addition, swimmers using SM+SC were significantly lower in record and strokes frequency than other groups.

One of the key issues in motor learning research is determining effective training conditions and providing feedback information to facilitate learning and performance improvement to the learner.[8]

We showed that SM and SC feedback in swimmers and waterpolo players led to a learning improvement. Behavior is learned through observational learning, a process that aims to mix observation and physical practice, either in part or during an entire practice session, until the desired motor skill is achieved.[6,7] Often, researchers use another person such as the coach, trainer or team mate as models to use the modeling technique.[9,23] However, SM adopts more effectively the modeling technique strategies.[11] It has been suggested that the learner's understanding of his similarity with the model may justify the impact of modeling on performance.[24] The learner may perform better after observing a similar model than a non-similar model.[24]

Observing model is possible through three self-modeling techniques: feed forward SM, positive self-review SM and self-observation.[25] In this study, through self-observation, the learner observed his previous performance in the film without any interference. It has been suggested that using SM video promotes intrinsic motivation, self-satisfaction, self-esteem, self-efficacy beliefs, and physical performance of skill model in learners.[9] Self-observation method outperforms SM in butterfly swimming in retention test.[11] From a psychological point of view, the subjects thinks that should be evaluated by the coach at the end, and from this they will have more effort to improve technique and performance.[11] As well, SM outperforms in swimming than observation of the other person as a model which indicated that allowing the athlete to evaluate himself is more realistic than observing others' performance.[22] Nowadays, neurologists using functional MRI techniques have investigated the mechanisms and neural area involved in observing the model, reported that activation of the supplementary motor area causes activity of mirror neurons in the medial temporal lobe involved in information processing.[26,27] However, recent research has shown that the neurophysiological SM leads to more efficient neural mechanisms and functional responses compared to others, and mirror neurons involved in different areas of the occipital lobe, prefrontal cortex, temporal and parietal lobe and they are active during SM interventions than others' models.[25,28]

In this study, SM swimmers and waterpolo players were able to improve the 100 m freestyle performance. It seems that these sports do not receive proper feedback while swimming due to inadequate visibility of their bodies, and the filming of individual swimmers, especially for professionals who are fully aware of the technique, can lead to improved performance. Moreover, athletes who observed their modeling during practice are successful because of the similarity of their execution they observe. SM seems to be useful because it provides interventions for deciding on the action that is needed to improve performance in subsequent efforts. In other words, observing their model by emphasizing previous skillful experiences, or by creating a successful impression of future performance, enhances memory self-efficacy beliefs and thus improves overall performance.[10] It is stated that the athlete must believe that he/she is improving, this will lead to better SC results. And also, detecting motor errors and correcting them is better for the athlete.[25]

The present study showed that swimmers and waterpolo players performance improved after SM and SC feedback. In this research, we tried to investigate both performance improvement (record) and technique improvement (stroke frequency) in athletes. In SC feedback, the learner can request feedback when they are uncertain about how they are acting or when they feel their performance is weak.[3] Several studies have shown that reducing the frequency of feedback about knowledge of result has beneficial effects on motor skills learning.[12,29] After analyzing the feedback provided as well as the interviews with the learner after the research, it was found that the learner preferred SC after successful feedback requests. It appears that the benefit of SC feedback is greater with performance self-evaluation and the strategic decision to seek feedback when the athlete's performance is better. It was concluded that the reason for the usefulness of SC feedback was not only its motivational effect, but also the greater consistency of this type of feedback with the needs of the participants.[12,30] It was shown that if the learner had control over the time he received feedback during the acquisition phase, he would show better performance in the acquisition, retention, and transmission phases.[31] Because having control during training efforts acts as a powerful intrinsic motivator and will require more effort.[30,31]

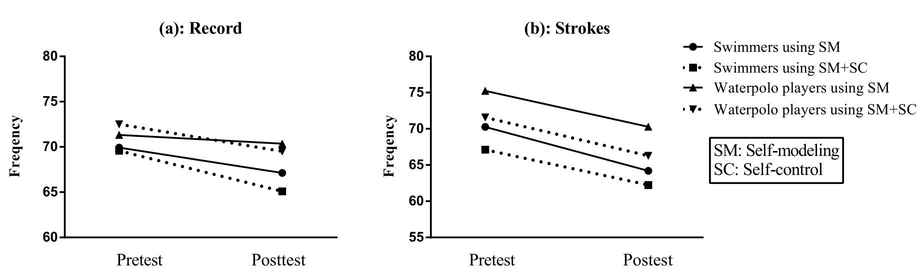

Fig. 2. Record (a) and strokes frequency (b) of swimmers in the 100-m freestyle for the four groups. SM: Self-Modeling, SC: Self-Control.
Abbrevaiations: Group 1 = swimmers using SM, Group 2 = swimmers using SM+SC, Group 3 = waterpolo playersusing SM, Group 4 = waterpolo players using SM+SC.

In swimmers and waterpolo players, the combination of SM and SC feedback may be more adaptable to learner needs, and may help further refine and learn skills. Some researchers have also claimed that the SC feedback indirectly leads to improved performance and learning by increasing effort on different motor strategies.[1,31] Another possibility assumed for the superiority of SC feedback is that this type of practice is more in line with the needs and preferences of performers than prescriptive programs.[32] In swimming and waterpolo, athletes who decided on the timing of receiving their feedback were likely to be more actively involved in the learning process and thus in greater information processing.[14] Perceived control and motivational stimuli may also be possible reasons to justify the effectiveness of this method.[10] In water sports, the participants do not have a good vision of their performance like on dry-land, and the skilled swimmers who have acquired the proper knowledge of how to properly apply the technique and know how to fight water resistance when watch own performance. However, there are also cases where the coach should help these swimmers, and this is when they ask the coach for help (augmented feedback).

The present study also showed that a combination of SM and SC feedback improved performance slightly more than SM in swimmers, but this difference was not statistically significant. Observation alone is not sufficient for learning and generating complex motor modeling unless augmented feedback is provided.[8,33] The researchers stated that observation and feedback interaction help to shape and refine the new movement. In fact, by observing the model, the learner understands what to do and generate a correction reference and the feedback is compared with the correction reference. Then, the refinement of the skill is gradual and the ability to detect errors is increased.[33] Verbal feedback was related to correcting skill execution by reducing errors.

The results showed that there was a significant difference between swimming performance in swimmers and waterpolo players. Individual sports use more skills and techniques than team sports and team athletes use more strategy functions.[21] It seems that swimmers, whose nature is individually placed in the closed skills category, have a direct positive impact on swimmer record by improving performance and technique, which causes swimmers to pay particular attention to technique modification.[14,20] The length of the training season would seek to reduce the record and improve performance, while in water polo because of being in the open skill category and interacting with your opponent and perhaps not directly affecting the swim performance on the game does not give players the motivation to fully refine the technique.[20] Also, these players are more involved in tactical and technical issues in the game, and the capacity to pay more attention to these issues. In the cognitive perspective, SC means putting more pressure on the learner.[3] On the basis of their abilities and knowledge of the task, they have to decide on their learning when and how to request feedback.[29] This puts a lot of pressure on the learner and divides one's attention capacity between learning and SC processes.[12] These contrasting effects of cognitive and motivational processes during the acquisition phase during SC in individual sport orient learner to focus on the technique modification and the record improvement.[14,29] However, waterpolo teamwork focus on game tactics, perhaps due to differences in performance improvement in individual and team sports.[14] The results of this study showed that SC feedback of watching an own video is a good way for professional swimmers. Waterpolo coaches can also use SM and SC feedback to enhance their players' swimming technique.

The practical point of view of this research is based on the fact that self-modeling alone and with self-control feedback leads to improvement in technique and performance in swimming and waterpolo players, and this improvement is more in the individual sport of swimming, and perhaps the reason is that all attention is focused on correcting the technique and improving the record, but in the group waterpolo players, more attention is paid to the tactics of the game.

From a practical point of view, perhaps the main reasons are:

i Identifying and augmented feedback time by the athletes;
ii Seeing the technical false in a video of own model and need for augmented feedback;
iii More self-efficacy and motivation in athletes after self-modeling;
iv Detecting motor errors and correcting them is better for the athletes.

Although this study has considerable practical application, a limitation of the study was the no measurement of the intrinsic motivation, the intelligence quotient and swimmers' trainability. For a deep explanation of the findings of the present study, future research should add the measurements of the intrinsic motivation, the intelligence quotient and swimmers' trainability. Lack of control group was the other limitation because highly trained swimmers and waterpolo players are not a lot in Qazvin province in Iran.

For future research, it is suggested to examine the SM and SC feedback during the practice and play of waterpolo and to modify the technique and tactics of the coach from the video recorded in subsequent training sessions. Finally, the results of this research can be used as a guide by the swimming and waterpolo coaches to design training seasons.

5. Conclusion

The present study indicates that SC modeling of watching video is a suitable method for professional swimmers who can imitate the targeted behavior. Water polo players can also use SM and SC feedback to enhance their players' swimming technique.

Ethical approval statement

The research was approved by the local ethics committee Imam Khomeini International University (ref. no. 17628), which was performed in accordance to the seventh and current revision (World Medical Association, 2014) of the Declaration of Helsinki. In order to adhere to the research ethics, all subjects were required to provide their informed consent.

Authors' contributions

Conceptualization, M.S., M.M., M.T., and K.I.; methodology, M.S., M.M., M.T., and K.I; investigation and resources, M.S., M.M., M.T., K.I., M.S, and F.M.; writing and editing, M.S., M.M., M.T., K.I., M.S., F.M., A.S., L.H., K.W., B.K., and A.G; project administration, M.T., and K.I.; supervision, B.K., and A.G. All authors read and approved the manuscript.

Submission statement

All authors have read and agree with manuscript content. The manuscript has not been published and is not under consideration for publication elsewhere.

Conflict of interest

The author declares no conflicts of interest relevant to the content of this paper. This study did not receive any funding.

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