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ORIGINAL RESEARCH

IMMEDIATE EFFECTS OF DEEP TRUNK MUSCLE TRAINING ON SWIMMING START PERFORMANCE

Satoshi Iizuka, MS[1]
Atsushi Imai, PhD[2]
Keisuke Koizumi, MS[3]
Keisuke Okuno, MS[2]
Koji Kaneoka, MD, PhD[2]

ABSTRACT

Background: In recent years, deep trunk muscle training has been adopted in various sports, including swimming. This is performed both in everyday training and as part of the warm-up routine before competitive races. It is suggested that trunk stabilization exercises are effective in preventing injury, and aid in improving performance. However, conclusive evidence of the same is yet to be obtained. The time of start phase of swimming is a factor that can significantly influence competition performance in a swimming race.

Hypothesis/Purpose: If trunk stabilization exercises can provide instantaneous trunk stability, it is expected that they will lead to performance improvements in the start phase of swimming. The purpose of this study was to investigate the immediate effect of trunk stabilization exercises on the start phase in swimming.

Study Design: Intervention study

Methods: Nine elite male swimmers (mean age 20.2 $\pm$ 1.0 years; height 174.4 $\pm$ 3.5 cm; weight 68.9 $\pm$ 4.1 kg) performed the swimming start movement. The measurement variables studied included flying distance, and the time and velocity of subjects at hands' entry and on reaching five meters.

Measurements were taken in trials immediately before and after the trunk stabilization exercises. A comparison between pre- and post-exercise measurements was assessed.

Results: The time to reach five meters (T_{5m}) decreased significantly after trunk stabilization exercises, by 0.019 s ($p = 0.02$). Velocity at entry (V_{entry}) did not demonstrate significant change, while velocity at five meters (V_{5m}) increased significantly after the exercises ($p = 0.023$). In addition, the speed reduction rate calculated from V_{entry} and V_{5m} significantly decreased by 5.17% after the intervention ($p = 0.036$).

Conclusion: Trunk stabilization exercises may help reduce the time from start to five meters in the start phase in swimming. The results support the hypothesis that these exercises may improve swimming performance.

Levels of Evidence: Level 3b

Keywords: Competitive swimmer, intervention, speed reduction

[1] Graduate School of Sport Sciences, Waseda University, Saitama, Japan
[2] Faculty of Sport Sciences, Waseda University, Saitama, Japan
[3] Tokyo College of Sports and Recreation, Tokyo, Japan

CORRESPONDING AUTHOR
Koji Kaneoka, MD, PhD
Faculty of Sport Sciences, Waseda University, Saitama, Japan
2-579-15 Mikajima, Tokorozawa Saitama, 359-1192, Japan
Phone: +81-4-29476958
E-mail: kaneoka@waseda.jp

INTRODUCTION

The deep trunk muscles, such as the transversus abdominis and the internal oblique, play an important role in stabilizing the trunk. Several researchers have reported that exercising these muscles enhances performance and prevents injuries.[1-5] Based on the results of these studies, stabilization exercises aimed at training deep trunk muscles are considered fundamental to exercises programs for strength and conditioning.[6] In recent years, the stabilization exercises have come to be prescribed for athletes in a variety of sports.

Because the trunk centers the movement of the extremities through the swimming motion, increased trunk stability, led by the deep trunk muscles, may improve performance.[7] Trunk stabilization exercises are often performed by swimmers as part of their daily routine, and for pre-race warm-up. A study by Weston et al has already shown the beneficial effects of trunk stabilization exercises on 50 m front crawl times.[5]

A swimming race may be divided into four phases: start, stroke, turn, and finish. Since the highest acceleration is gained during the start phase, it is critical in determining overall swimming performance.[8, 9] In the start phase, swimmers kick back against plates on the starting block to increase horizontal speed. Preliminary research, focusing on the lower limbs at the start, showed that performance improved immediately when lower-limb training was performed as part of the warm-up.[10] Additionally, the deceleration due to water resistance at the moment of entry is important and if able to be minimized could be beneficial for overall time reduction.

It has been reported that facilitation of the deep trunk muscles increases stability of the body.[11] Due to the increase in stability, it is postulated that the body becomes more rigid. Authors have described the influences of stability on the body as important to the control of a variety of movements.[12,13] Trunk stability is essential in order to gain high start velocity and reduce water resistance during diving. Increased rigidity of the trunk can assist in efficient transmission of the propulsion force from the body to the back plates. The trunk muscles also help to maintain streamlined, which reduces water resistance during entry. If stabilization exercises can provide instantaneous trunk stability, enhanced performance in the start phase may be expected. Previous researchers have demonstrated the immediate effect of trunk stabilization exercises in improving performance on the rebound jump that repeats the vertical jump with a countermovement arm swing.[14] If trunk stabilization exercises can provide instantaneous trunk stability, it is expected that they will lead to performance improvements in the start phase of swimming. The purpose of this study was to investigate the immediate effect of trunk stabilization exercises on the start phase in swimming.

METHODS

Participants

Nine elite male swimmers (mean age 20.2 ± 1.0 years; height 174.4 ± 3.5 cm; weight 68.9 ± 4.1 kg) from the University swimming team took part in the study. All participants were experienced, national-level swimmers. The swimming style of the participants was not considered. Swimmers who had pain or injuries in any of the body parts that influenced swimming were excluded. All participants were provided with, and signed, written informed consent forms before participation. The study was approved by the Ethical Committee of Waseda University.

Procedures

The starting block used in this study was manufactured by Seiko (Tokyo, Japan). For each subject, the position of the movable back plate on the starting block was adjusted to a race setting. Two high-speed video cameras (HAS-220, DITECT Co., Tokyo Japan) were used to record the starting motion. One camera was placed on the side of the starting block, while the other was placed five meters away from the starting block, in the water. Recording frequency was set at 200 frames per second. Eight self-emitting LED markers (Kirameki, Nobby Tech. Ltd., Tokyo, Japan) were attached on anatomical landmarks on the right side of the subjects at the ulnar styloid process, the olecranon, the acromion, the anterior superior iliac spine, the posterior inferior iliac spine, the great trochanter, the head of the fibula and the lateral malleolus. By tracking each marker, the starting motion was analyzed using three-dimensional motion analysis software (Frame-DIAS V, DKH Co., Ltd., Tokyo, Japan). Prior to measurement, subjects were allowed a warm-up session of approximately 10 minutes, for the starting motion. Two or more repetitions starting motions were included in the warm-up. For the measurement, subjects performed the starting motion, cued by the starting signal used in race conditions. After the first starting trial (pre-exercise measurement), the subject performed the trunk stabilization exercises. The starting trial was repeated immediately after the exercises (post-exercise measurement). A previous study showed reliability and validity of the procedure used for measurements and analysis in water.[15]

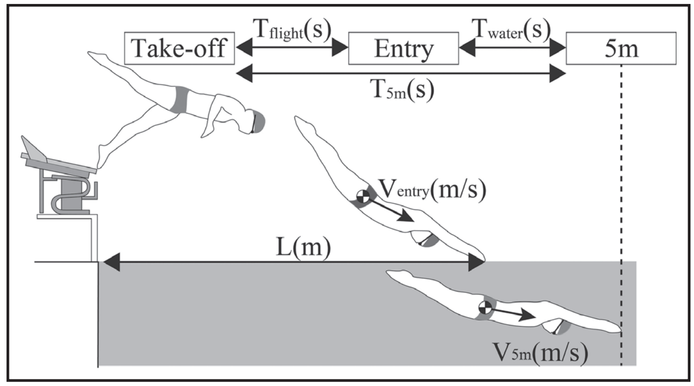

Figure 1. *Diagram of the definitions of variables. L is the flight distance from wall to entry point of the hands. T_{flight} is the time from the take-off to entry. T_{water} is the time from the hands entry to the hand crossing the imaginary line at five meters. T_{5m} is the summed time of T_{flight} and T_{water}. V_{entry} is magnitude of the velocity of the great trochanter marker at the hands entry. V_{5m} is magnitude of the velocity of the great trochanter marker at the hand crossing the imaginary line at five meters.*

Variables

The study assessed performance of the starting motion for distance, time, and velocity. Flight distance (L) was measured as the distance from the wall of the pool to the point where the hands enter the water. The timing of hand enter was defined when the fingertip touched the water surface. The timing was confirmed visually from the view of camera in the water. In the same way, reaching five meters was also judged when the fingertip reached a distance five meters from the same camera.

This value was calculated after conversion into real length from a moving image using two-dimensional Direct Linear Transformation (DLT) method.[16] To measure time, the starting motion was divided into two phases. The first phase named the flight phase (T_{flight}), was defined as the time between the back foot taking off and the hands' entry into the water.. The second phase, named the water phase (T_{water}), was defined as the time from the hands' entry into the water to reaching five meters. The sum of T_{flight} and T_{water} represents the total time, T_{5m}. In addition, the instantaneous velocity at entry (V_{entry}) and at five m (V_{5m}) were calculated by tracking the LED marker on the greater trochanter (Figure 1).

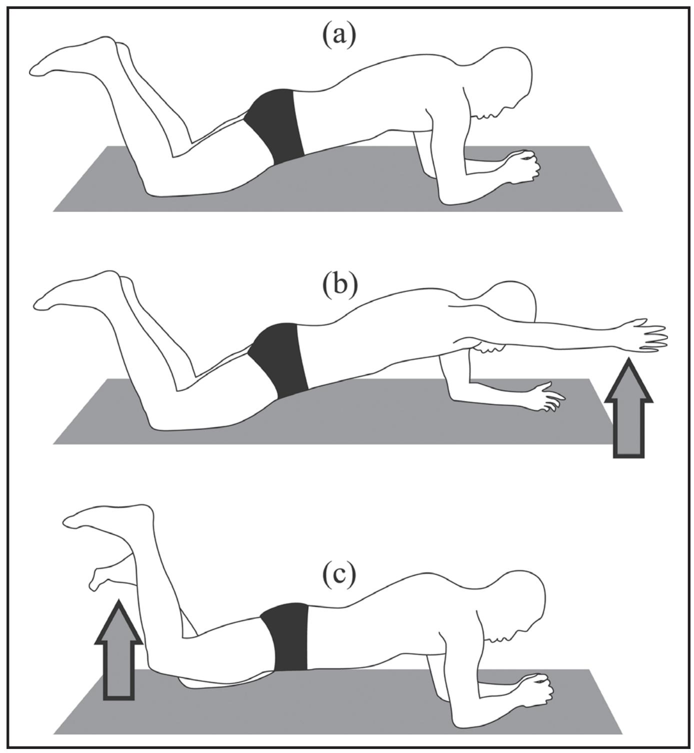

Figure 2. *Stabilization exercises intervention; (a) elbow-knee (held for 60sec), (b) elbow-knee with alternative arm raise (30 times), (c) elbow-knee with alternative leg raise (30 times)*

Intervention

The pilot study demonstrated that trunk stabilization exercises may activate deep trunk muscles.[17] There were three trunk stabilization exercises used during the study namely, the elbow-knee position held for 60 seconds, the alternating arm raise in the elbow-knee position for 30 repetitions, and the alternating leg raise in the elbow-knee position for 30 repetitions (Figure 2). A resting time of 15 seconds was allocated between exercises. These exercises are also used by the Japanese national swim team as a pre-race warm-up (Figure 3). A previous study showed that 30 % of the maximum voluntary con-

Figure 3. *Actual warm up exercises performed before the swimming race in London Olympics.*

traction (transversus abdominis: TrA) was sufficient to control the stability of lumber segments.[18] Regarding trunk stabilization exercises, adequate activity of the deep trunk muscles was obtained by Hand-Knee exercise procedure.[17] Based on the results of these studies, suitable interventions for swimming were chosen and employed in this study.

Statistical Analysis

The average value and standard deviation of each performance variable were calculated. The pre-and post-exercise measurements were compared using a dependent t-test. Statistical analysis software (SPSS Statistics 21, IBM Japan Inc.) was used for the analysis, with the alfa level set at 5%. Effect size was calculated using Cohen's *d* to establish the strength of the differences between each trial. The scale to interpret the strength of the effect size was: 0-0.2 small; 0.2-0.6 moderate; >0.8 large.[19]

RESULTS

Table 1 shows each performance variable, pre- and post-trunk stabilization exercises. The time, T_{5m}, decreased significantly after the exercises, by 0.019 s ($p=0.02$), although there was no significant change in T_{flight} and T_{water} separately. V_{entry} did not demonstrate a significant change, although V_{5m} increased significantly after the exercises ($p=0.023$). The rate of speed reduction calculated between V_{entry} and V_{5m} decreased significantly, by 5.17% after the intervention ($p=0.036$). L did not show significant variation in the two measurements. (Figure 4)

DISCUSSION

Although trunk stabilization exercises have been used in a variety of sports disciplines, their effect on performance has not yet been clarified. This study investigated the effect of the trunk stabilization exercises on simulated race start performance. Flight distance from the starting block to the point of water entry, and the time to reach the point of entry and then five meters, were used as performance values in this study. The results suggest that velocity at five meters from the start increased following stabilization intervention. However, trunk stabilization exercises did not alter the flight distance. An earlier study reported that trunk stabilization exer-

Table 1. *Means and standard deviations obtained for each variable.*

	Pre	Post	p-value	ES
L (m)	3.14±0.31	3.19±0.30	0.172	0.16
$T_{flighet}$ (s)	0.422±0.085	0.423±0.086	0.917	0.01
T_{water} (s)	0.407±0.085	0.387±0.074	0.112	0.26
T_{5m} (s)	0.829±0.037	0.810±0.039	0.020*	0.52
V_{entry} (m/s)	5.28±0.20	5.27±0.27	0.842	0.06
V_{5m} (m/s)	4.61±0.46	4.87±0.35	0.023*	0.63

Mean±SD *significant difference ES: Effect Size

Abbreviations; L: the flight distance from wall to entry point of the hands. T_{flight}: the time from the take-off to entry. T_{water}: the time from the hands entry to the hand crossing the imaginary line of 5m. T_{5m}: the summed time of T_{flight} and T_{water}. V_{entry}: magnitude of the velocity at the hands entry. V_{5m}: magnitude of the velocity at the hand crossing the imaginary line of 5m.

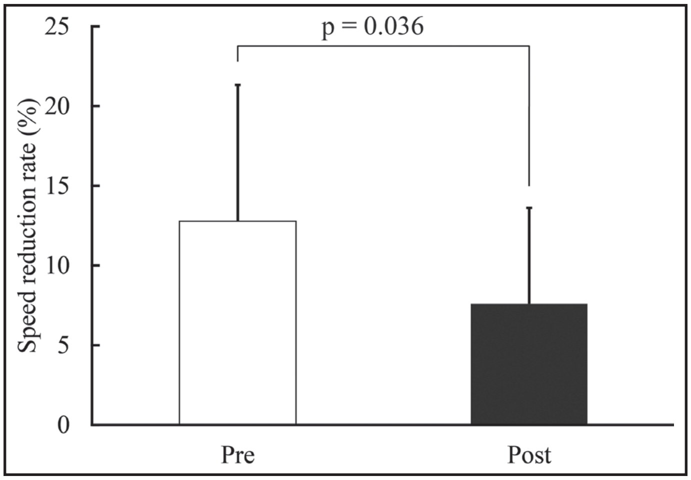

Figure 4. *Means and standard deviations obtained in the speed reduction rate.*

cise interventions could immediately increase jump height measured in rebound jumps performed on the ground.[14] However, the findings regarding the relationship between the vertical jump ability and starting performance in swimming are inconclusive. One study demonstrated a positive correlation between them.[20] On the contrary, Ray et al reported that improvement of the vertical jump did not lead to enhancement in starting performance.[21] The results of the present study indicate that trunk stabilization exercises did not have an immediate effect on the flight distance during the starting motion. The positive correlation between lower-limb warm-up exercises and flight distance observed in the authors earlier intervention allows conjecture that trunk stabilization exercises alone are insufficient in improving flight distance.[10] The time taken to reach five meters, T_{5m}, decreased by 0.019 s ($p = 0.02$) after the exercises. This time reduction may be considered insignificant, but an improvement by 0.02 s is meaningful when results in a competitive swimming race may be decided by as little as one millisecond. For example, in results from a recent national race in japan, rank was changed by a difference of 0.02 s.

In addition to, V_{5m} increased significantly. The pre-exercise V_{5m} was 4.61 ± 0.46 (m/s), but it became 4.87 ± 0.35 (m/s) in the post-exercise measurement, confirming a significant improvement in speed ($p = 0.023$). However, because V_{entry} remained unchanged after the intervention, trunk stabilization exercises may not affect the transmission of propulsion force to the back plates on the starting block. A computer simulation model demonstrated that there was a strong resistance against the shoulders and thorax at the moment of entry moment.[22] Unless the trunk maintains a stable, straight line during entry, swimmers greater water resistance, due to less streamlined in the water. This less streamlined can further increase water resistance and may lead to deceleration. Trunk stabilization exercises can quickly activate the deep trunk muscles in order to minimize unnecessary trunk movement against water resistance at entry. This suggestion is supported by the results, which show that the speed in the water was not decreased and higher velocity could be maintained at the five meter point.

The findings of this study support the hypothesis that trunk stabilization exercises may lead to immediate improvements in starting performance, and may reduce swimming race timing. An immediate improvement in performance indicators was observed even though the participants performed similar exercises in their daily routine. The results indicate the beneficial effects of including trunk stabilization exercises as part of the warm-up routine.

The applicability of the study's findings is somewhat limited by the lack of a control group comprised of people who do not exercise regularly. This study only investigated the acute/short term effects, and thus, it remains unknown how long the effects of these exercises last. Further research is required to clarify the effects of trunk stabilization exercises and how long it lasts on swimming performance.

Although participants performed same warm up procedure as a race, only one trial was measured at pre and post interventions respectively. Thus, it is difficult to negate a learning effect, which is a limitation of this study. In addition, since intensity of the training intervention was moderate level, there is a possibility that higher intensity programs may lead to superior results. A between-group design will be required for further study to confirm how much level of the intervention results in the best performance.

CONCLUSIONS

Intervention in the form of trunk stabilization exercises may reduce the time from start to five meters in the start phase of swimming, which may improve overall swimming performance.

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