THE EFFECTS OF 8 WEEKS CORE COMBINED LOWER LIMB STRENGTH TRAINING ON ADOLESCENT SWIMMERS' MEDLEY TURNING TECHNIQUE

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This study aimed to explore the effects of core combined lower limb strength training on medley turning technique of adolescent swimmers. Ten adolescent swimmers completed the trunk extensor and flexor endurance tests, squat jump test and 200m individual medley race before and after the 8 weeks training. The time of extensor and flexor endurance, jump height, and the maximal acceleration in swimming turns had significantly increased after training. The -5 m to 5 m times, the tuck times, and the hip and knee joint angles had significantly decreased after training. Eight weeks core combined lower limb strength training can improve the core strength and lower limb power, optimize the tuck technique, reduce the -5 m to 5 m time and increase the maximum acceleration during the swimming turns in 200m individual medley.

KEYWORDS: core combined lower limb strength training; adolescent swimmers; individual medley; turning technique

INTRODUCTION: Except for the clean swimming, the turn is the most used technical maneuver during all long course events greater than 50m in competitive swimming (Nicol et al., 2018). The effect of turns on swimmers' performance increases with race distance (Slawson et al., 2010), and the turning performance directly affect the speed of the next stroke and the subsequent clean swimming (Nicol et al., 2019).
The core is the center of the functional kinetic chain as well as the basis of limb movement (Akuthota et al., 2004). During swimming, a well-stabilized core can maintain body streamlining and enhance the effective transfer of force between the trunk and upper and lower limbs, thus improving movement effectiveness (Patil et al., 2014). Swimmers with good lower limb strength could generate greater reaction force when push off the wall during the swimming turns, which can increase the swimming speed and improve final performance (Lindley, 2001).
Current research is more focused on the effect of core and lower limb strength on performance in clean swimming, with little focus on turning performance. The aim of this study was to clarify the effects of the eight weeks core combined lower limb strength training on individual medley turning technique by comparing the parameters of swimming turns as well as core and lower limb strength parameters before and after training.

METHODS: Ten national-level adolescent female swimmers (age = 14.5 ± 0.8 years, height = 165.3 ± 3.2 cm, weight = 51.8 ± 4.1 kg) participated in this study.
The core combined lower limb strength training includes TRX (Total Body Resistance Exercise) suspension training and squats training. This training program was performed 3 times per week for 8 weeks. The duration of the training did not exceed 90 minutes, with a 1-min interval between sets. The details of the training program are presented in Table 1.

Core endurance test includes trunk extensor and flexor endurance tests. Extensor endurance was performed using the Biering-Sorensen test and flexor endurance was conducted using the movement in the opposite direction to the extensor endurance test. Time was recorded until subject could no longer control his/her posture for a maximum of 300 s.

Squat jump test (SJ) was performed by Kistler MARS system (Kistler Instrument, Switzerland) to assess muscle power of the lower limb. Three SJ were performed at a 2-minute interval for each test. Jump height were recorded and only the best performance was retained for statistical analysis.

Table 1 The 8-week core combined lower limb strength training program

Exercises	Week of training(S*R)				
	Week 1	Week 2-3	Week 4-5	Week 6-7	Week 8
Reverse crunch	3*10	4*12	5*15	5*15	3*15
Glute bridge	3*10	4*12	5*15	5*15	3*15
Rotational side plank	3*10	4*12	5*15	5*15	3*15
Squats	3*6(80%1RM)	4*5(85%1RM)	5*5(85%1RM)	5*5(85%1RM)	3*5(85%1RM)

S: sets; R: repetitions.

Three 200 m individual medley races were performed at a 20-minute interval for each race and only the best performance was retained for statistical analysis. The race was recorded with six stationary and genlocked cameras: four underwater video cameras and two digital video cameras operating at a sampling rate of 60 Hz. The calibration frame was designed as a rectangle (2 × 1.5 × 1 m, for the X, Y and Z axes, respectively), with the X-axis aligned horizontally in the direction of swimming and the Y and Z axes being vertical and lateral, respectively. The cameras and frame positions are illustrated in Fig.1. The underwater cameras were placed 40 cm under the water and the digital cameras were placed 3 m above the water. Two underwater cameras on the same side were synchronized. Each participant was fitted with one TritonWear sensor (Triton 2, Canada) behind the head and below a swimming cap to monitor the performances, which can collect the acceleration of swimming turns.

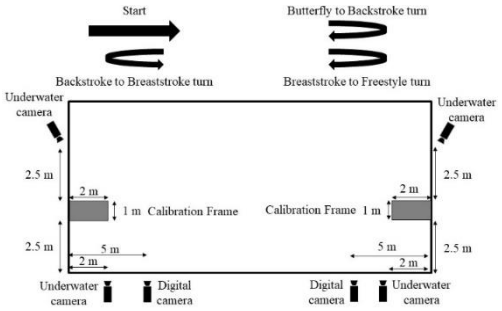

Figure 1 Cameras and calibration frame positions

For the race video, Ariel Performance Analysis System (Ariel Dynamics inc., USA) was used to analyze to obtain the hip and knee joint angles, the tuck time, and the -5 m to 5 m time. Eight body landmarks (shoulders, hips, knees, and ankles) were digitized for each frame. The calculation of 3D coordinates relied on the Direct Linear Transformation (DLT) method incorporated into APAS. The hip joint angle was defined as the minimal angle between the torso and the thigh during the swimming turns. The knee joint angle was defined as the angle between the thigh and the calf during the swimming turns. The tuck time was defined as the time lag between the time touching the wall and the moment the hip joint angle is at its minimum. The -5 m to 5 m time was defined as the time occurring the swimmer's head passing the 5 m

mark prior to the turning wall and the swimmer's head passing the 5 m mark after pushing off (Polach et al., 2021). The TritonWear device can automatically compute the acceleration in swimming turns. The maximal acceleration was defined as the peak acceleration during push off phase in swimming turns.

All data are presented in mean ± standard deviation and analyzed by the SPSS Statistics V19.0 software. The differences in variables between before and after training were compared with Paired Samples T-test. Effect sizes (d) were estimated by calculating the 95% confidence intervals for Cohen's d.

RESULTS AND DISCUSSION: The means and standard for various measurements are presented in Table 2. The time of extensor and flexor endurance and jump height were significantly improved after eight-week training, suggesting that core and lower limb muscles' strength were increased.

Table 2 Pre- and post-training vales of variables for adolescent swimmers

Variables	Pre-training	Post-training	*p*	Effect size
Core test				
Extensor endurance (s) **	81.0 ± 10.4	128.5 ± 8.1	0.005	5.16
Flexor endurance (s) **	95.5 ± 11.9	145.0 ± 10.2	0.005	5.34
Squat Jump test				
Jump height (m) *	0.24 ± 0.02	0.26 ± 0.04	0.042	0.70
-5 m to 5 m time				
BU to BA turn (s) **	6.98 ± 0.35	6.28 ± 0.33	0.004	2.05
BA to BR turn (s) *	7.02 ± 0.47	6.49 ± 0.28	0.018	1.40
BR to FR turn (s) **	7.71 ± 0.28	7.18 ± 0.30	0.002	2.85
Tuck time				
BU to BA turn (s)	1.36 ± 0.32	1.33 ± 0.29	0.379	0.01
BA to BR turn (s) *	1.48 ± 0.24	1.22 ± 0.15	0.028	0.98
BR to FR turn (s) *	1.15 ± 0.23	0.91 ± 0.22	0.034	0.78
Hip joint angle				
BU to BA turn (°) **	66.15 ± 19.37	57.65 ± 17.75	0.005	1.08
BR to FR turn (°) *	62.08 ± 9.53	54.25 ± 11.84	0.016	0.88
Knee joint angle				
BU to BA turn (°) **	43.72 ± 16.63	38.85 ± 14.11	0.009	0.97
BR to FR turn (°)	39.15 ± 10.93	35.85 ± 19.10	0.280	0.34
Maximal acceleration				
BU to BA turn (m/s^2) *	11.38 ± 1.42	14.11 ± 2.10	0.031	0.63
BA to BR turn (m/s^2) **	9.44 ± 1.35	12.91 ± 1.83	<0.001	2.82
BR to FR turn (m/s^2) *	8.86 ± 1.19	10.98 ± 1.81	0.040	0.60

BU: Butterfly, BA: Backstroke, BR: Breaststroke, FR: Freestyle, *p*: p-value

*Significant differences between pre- and post-training with $p < 0.05$

**Significant differences between pre- and post-training with $p < 0.01$

The hip and knee joint angles in swimming turns reflect the degree of tuck, and the smaller the joint angles, the greater the degree of tuck (Rejman et al., 2008). Our study found that the hip and knee joint angles of swimmers decreased significantly after 8-week training, indicating that the training played a role in promoting the swimmers' tuck maneuvers. In addition, swimmers' tuck times in BA/BR and BR/FR turns decreased significantly, indicating that training could accelerate the completion of tuck in swimming turns. The TRX core training in this study effectively improved the core strength of the swimmers, promoted the power chain transmission and the coordinated development of muscle strength in limbs, and led to a more powerful muscle contraction during the rotation phase, which reduced the hip and knee joint angles during the swimming turns and resulted in a tighter tuck.

The maximum acceleration in the swimming turns occurs in the push off phase, the greater the maximum acceleration the greater the push-off velocity. In medley, the push-off velocity affects the initial velocity and technique of the next stroke (Weimar et al., 2019). In present study, the maximum acceleration of all three swimming turns increased after training, which was associated with increased lower limb strength and power.

The core combined lower limb strength training used in this study improved the endurance and fatigue resistance of the core muscle groups, improved the movement posture and the efficiency of energy transfer between swimming turns, and provided a solid foundation for the full utilization of lower limb strength, which is why a significant reduction in the swimmers' -5 m to 5 m times was observed in our study.

The limitation of this study is that there was no control group, so the results of the study do not circumvent the effects of normal training on performance in adolescent swimmers. However, in some studies of adolescent swimmers, it was found that there was no significant change in the performance before and after 8 weeks of normal training (Eskiyecek et al., 2020; Gencer, 2018), suggesting that adolescent swimmers do not make substantial gains in performance in a relatively short period of time.

CONCLUSION: Eight weeks core combined lower limb strength training can improve the core strength and lower limb power in adolescent swimmers, optimize the tuck technique, reduce the -5 m to 5 m time and increase the maximum acceleration during the swimming turns in 200m individual medley.

REFERENCES

Akuthota, V., Nadler, S. F. (2004). Core strengthening. Archives of physical medicine and rehabilitation, 85, 86-92.

Eskiyecek, C. G., Gül, M., Uludağ, B., Gül, G. K. (2020). The Effect of 8-Week Core Exercises Applied to 10–12 Age Male Swimmers on Swimming Performance. Int. J. Appl. Exerc. Physiol, 9, 213-220.

Gencer, Y. G. (2018). Effects of 8-Week Core Exercises on Free Style Swimming Performance of Female Swimmers Aged 9-12. Asian Journal of Education and Training, 4(3), 182-185.

Lindley, S. L. (2001). Kinematic analysis of freestyle and backstroke flip-turns in competitive swimming.

Nicol, E., Ball, K., Tor, E. (2018). The characteristics of an elite swimming turn. ISBS Proceedings Archive, 36(1), 869.

Nicol, E., Ball, K., Tor, E. (2019). The biomechanics of freestyle and butterfly turn technique in elite swimmers. Sports Biomechanics.

Patil, D., Salian, S. C., Yardi, S. (2014). The effect of core strengthening on performance of young competitive swimmers. International Journal of Science and Research, 3(6), 2470-2477.

Polach, M., Thiel, D., Kreník, J., Born, D.-P. (2021). Swimming turn performance: the distinguishing factor in 1500 m world championship freestyle races? BMC Research Notes, 14, 1-7.

Rejman, M., Borowska, G. (2008). Searching for criteria in evaluating the monofin swimming turn from the perspective of coaching and improving technique. Journal of sports science & medicine, 7(1), 67.

Slawson, S., Conway, P., Justham, L., Le Sage, T., West, A. (2010). Dynamic signature for tumble turn performance in swimming. Procedia Engineering, 2(2), 3391-3396.

Weimar, W., Sumner, A., Romer, B., Fox, J., Rehm, J., Decoux, B., Patel, J. (2019). Kinetic analysis of swimming flip-turn push-off techniques. Sports, 7(2), 32.