International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

The Effect of Core Strengthening on Performance of Young Competitive Swimmers

Dr. Dnyanesh Patil[1], Dr. Shivani Chowdhury Salian[2], Dr. Sujata Yardi[3]

[1]Assistant Professor, Department of Physiotherapy, D.Y. Patil University, Nerul, Navi Mumbai, India

[2]Professor, Department of Physiotherapy, D.Y. Patil University, Nerul, Navi Mumbai, India

[3]Advisor, Department of Physiotherapy, D.Y. Patil University, Nerul, Navi Mumbai, India

Abstract: ***Study design: Randomized control trial Objectives: To assess the added effect of core strengthening on performance within young competitive swimmers. Background: There have been studies in the past which evaluated efficacy of various exercise protocols in improving performance in young competitive swimmers. This improvement was expressed in terms of changes in the values of sprint time and stroking characteristics. The need of the hour has favored us answer this research question regarding the efficiency of core strengthening program in improving the performing in the young competitive swimmers. Methods: 60 young competitive swimmers (mean±SD, Age 14.2 ± 1.49) participated in the study of both sexes divided in two groups. (N= 60, n1= 30, n2= 30). Outcome measures were evaluated before and after 6 weeks of an additional core strengthening. Repeated measures ANOVA, Friedman test, Unpaired t-test and Mann Whitney U test were used to analyze their performance. Results: Significant differences between values of outcome measures were noted between experimental and control group at p < 0.05. Conclusion: Added core muscle strengthening enhanced the performance in young competitive swimmers projected as significant improvements in 50m freestyle sprint time, velocity and stroke index. Level of Evidence: Therapy, level 1b.***

Keywords: Freestyle swimmers, Stroke Index, Stroke Length, Stroke Rate, Swim velocity.

1. Introduction

The objective of competitive swimming is to cover a given distance in water in the least possible time[2, 17]. Performance in swimming depends on generating propelling power and minimizing the resistance to movement in water[17, 25]. Excelling in swimming records requires the swimmers to be more specific and rigorous in their training regime which has improved over the years garnering more support from sport science[20, 28]. Dry land training is an integral part of the training program for swimmers currently on the basis of evidence substantiated through research work[19,26]. Many studies have not been able to draw fulfilling conclusions as regards the relationship between improvements of strength on dry land and performance of swimmers in water[19]. Studies in the past have inferred that dry land strength training lack the positive transfer between dry land gains and swimming propulsive force due specificity of training[27].

Maintaining a streamlined body position and balance is one of the critical factors in improving the efficiency of a swimmer's performance, which in turn depends on the strength of the core muscles[23]. Unlike other ground based sports swimming has no ground pushing back to limit the way in which the body can move and adjust the center of gravity to maintain balance, and therefore the core muscles have to be as strong as possible to carry out similar functions of balance and movement in water [13, 23].
Studies have also proven that there is a strong positive correlation between core muscles strength, buoyancy and finally swimming performance. Where sport specific skills are concerned, an athlete's core acts as a foundation of movement generation and power production leading to an improvement in the performance[4,8,16]. A strong core enables an athlete to execute more efficient and swift body movements thereby leading to a better force distribution from the fully developed core to the upper and lower body region[16]. In swimming the extremities which connect to the lumbar spine are responsible for propelling the body through water. A strong core will enable more energy to be transferred from the core to pull and keep the components of the stroke. A weak core will leak out more energy, resulting in less powerful and kick and hence it is important to develop a strong core in swimming[13].

However there is little evidence proving that the core muscle strength would be translated into improving the performance of swim time at large[26]. Regardless of the amount of strength a young athlete possesses in the upper and lower limbs, a weak core will ultimately decrease the total amount of power that can be accumulated[4,11].

Specific body composition and proportions in adolescent individuals affects the performance in swimming[12,17]. It is believed that rigorous swimming training must begin before puberty to make successful swimming champs[10,17]. Studies correlating swimming performance with physical traits and physical capacity in young swimmers are extremely limited[15,19]. Therefore, the purpose of this study is to find the effect of core training on the performance of young competitive swimmers. We hypothesized that core strengthening exercise program when added to the routine swim training program for swimmers brings about positive changes in the performance of young competitive swimmers.

2. Methods

2.1 Study subjects

Seventy nine swimmers were assessed for eligibility (n=79), out of which 19 swimmers did not met the inclusion criteria. Sixty (n=60) competitive swimmers were selected for the study in the age group of 14-18 for boys and 12-18 years for girls. The Demographic information of competitive swimmers with mean ± SD is shown in **Table 1**. The subjects included for this study were young competitive level swimmers who have participated in any competition of minimum school or club level swimmers between the ages, Girls 12-18, boys 14-18 who have been trained or coached for at least two years. Subjects with back pain in last six months, cardiovascular or neurological problems, giddiness or balance disorder or subjects undergoing any core training or strength training were excluded.

2.2 Test procedures

Prior to testing, all subjects were informed about the nature and course of the study and written assent was given followed by the parents giving their consent to allow their ward to participate in this study. The research proposal was approved by the ethics committee of D Y Patil University, Navi Mumbai. The subjects were assigned randomly to one of the two groups, for allocation of participants a computer generated randomly selected subset of subjects was used (http://www.graphpad.com/quickcalcs/randomize1.cfm).

Group 1: Experimental Group
Group 2: Control Group

All subjects became familiar with the testing procedures that took place approximately one week prior to session. During the pretest session, each subject received instructions from a therapist that explained and demonstrated proper execution of each exercise.

2.3 Outcome Measures

2.3.1 Swimming performance

Time taken to complete 50m distance. It was determined by using a stopwatch. All the swimmers performed maximal freestyle 50m over a 25m swimming pool.

2.3.2 Functional Core Muscle Strength Performance

[18]: For assessment specific motion patterns and quality of movement is done. The Core Muscle Strength Test was used to monitor the athlete's core strength. To undertake this test the subject requires a flat surface or a mat to support the elbows and arms and a stopwatch (**FIGURE 2**). If the subject is unable to hold any of these positions then the test is to be stopped. This Test is conducted by keeping the mat to support the elbows and arms to begin with the plank test position. Once the correct position is assumed the tester starts the stop watch.

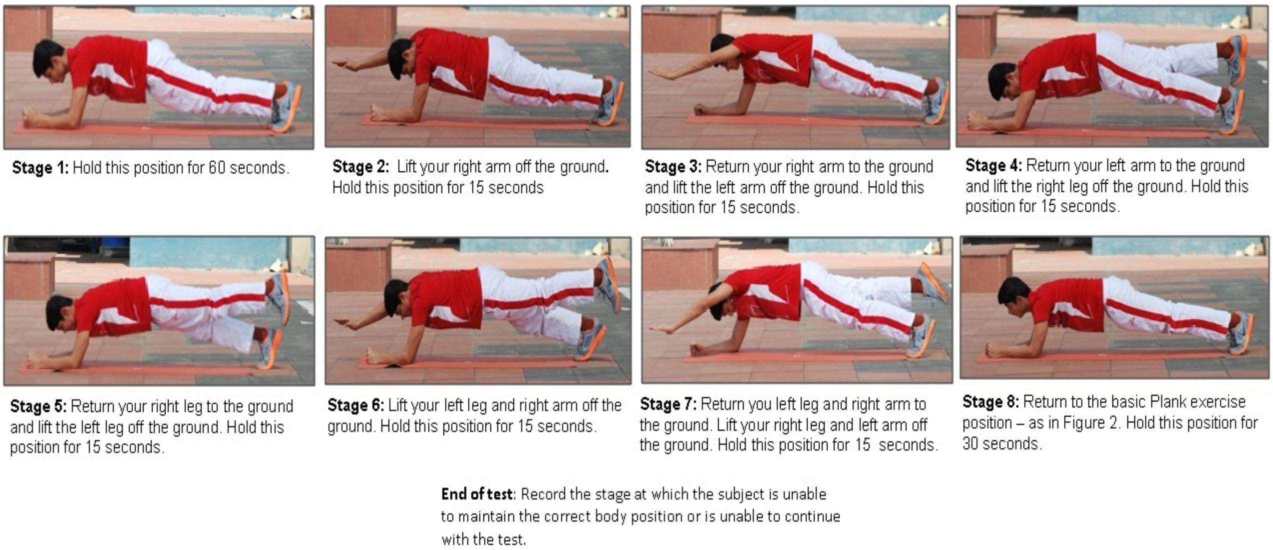

Figure 2: Functional Core Muscle Strength Performance

2.3.3 Stroke rate

The time required to perform 3 stroke cycles was measured and then used to calculate Stroke Rate

SR= 60 × 3/tSR (SR- Stroke Rate, tSR- time taken of 3 cycles)

2.3.4 Stroke length

The stroke length or distance per stroke was calculated by dividing the velocity by the stroke rate expressed in m.cycle

V = S/t (V- Velocity, S, Distance, t- time)

SL = V × 60/SR (SL- Stroke Length) [3]

The velocity was recorded as distance divided by time taken to complete the race.

2.3.5 Stroke index

The stroke index (SI) was defined by Costill et.al (1985) as the product of average velocity and stroke length and they considered it a valid indicator of swimming efficiency. The resulting units were $m^2 * (s.cycle)^{-1}$

SI= V × SL (SI- Stroke Index) [3]

2.4 Training Protocol

After the completion of all baseline measurements the subjects age and sex matched swimmers were selected and randomly assigned to each of both groups. Experimental group (Group 1) received core training along with the routine swimming training. All the group 1 participants were trained for 3 times a week for six weeks. Outcomes measures of both groups were collected after every 2 week until their end of training after 6 weeks. Six exercises were performed in one session as shown in

FIGURE 3: Exercises done in 1st & 2nd week of Experimental group (Group 1)
A) Prone Plane B) Side Plank C) Bridging D) Bird Dog E) Dying Bug F) Leg Drop

FIGURE 4: Exercises done in 3rd & 4th week of Experimental group (group 1)
A) Prone plank on swiss ball B) Side plank with leg lifts C) Bridging D) Dying Bug
E) Leg Drops F) Bird dog on ball

FIGURE 5: Exercises done in 5th & 6th week of Experimental group (Group 1)
A) Prone plank on ball with leg lifts B) Side plank with leg lift C) Bridging on ball
D) Dying Bug E) Leg Drop exercises on ball F) Bird Dog on ball

Figure 3, 4 and 5: The duration of the each session lasted for 30 minutes to 1 hour.

3. Statistical Analysis

Data was analyzed using SPSS 15.0. Means ±SD were calculated for each variable. Baseline outcome variables were analyzed after six weeks using a repeated measure analysis of variance for 50 m freestyle sprint time, stroke rate, stroke length, swim velocity, and stroke index and Independent student's t- test for comparison within the groups and between two groups respectively. Similarly Friedmann test for functional core muscle strength test for comparison within groups and Mann Whitney U test for comparison between the two groups. Statistical significance was set at $p \leq .05$. A Bonferroni correction for multiple comparisons was used for post hoc analysis. All data are presented as Mean ±SD.

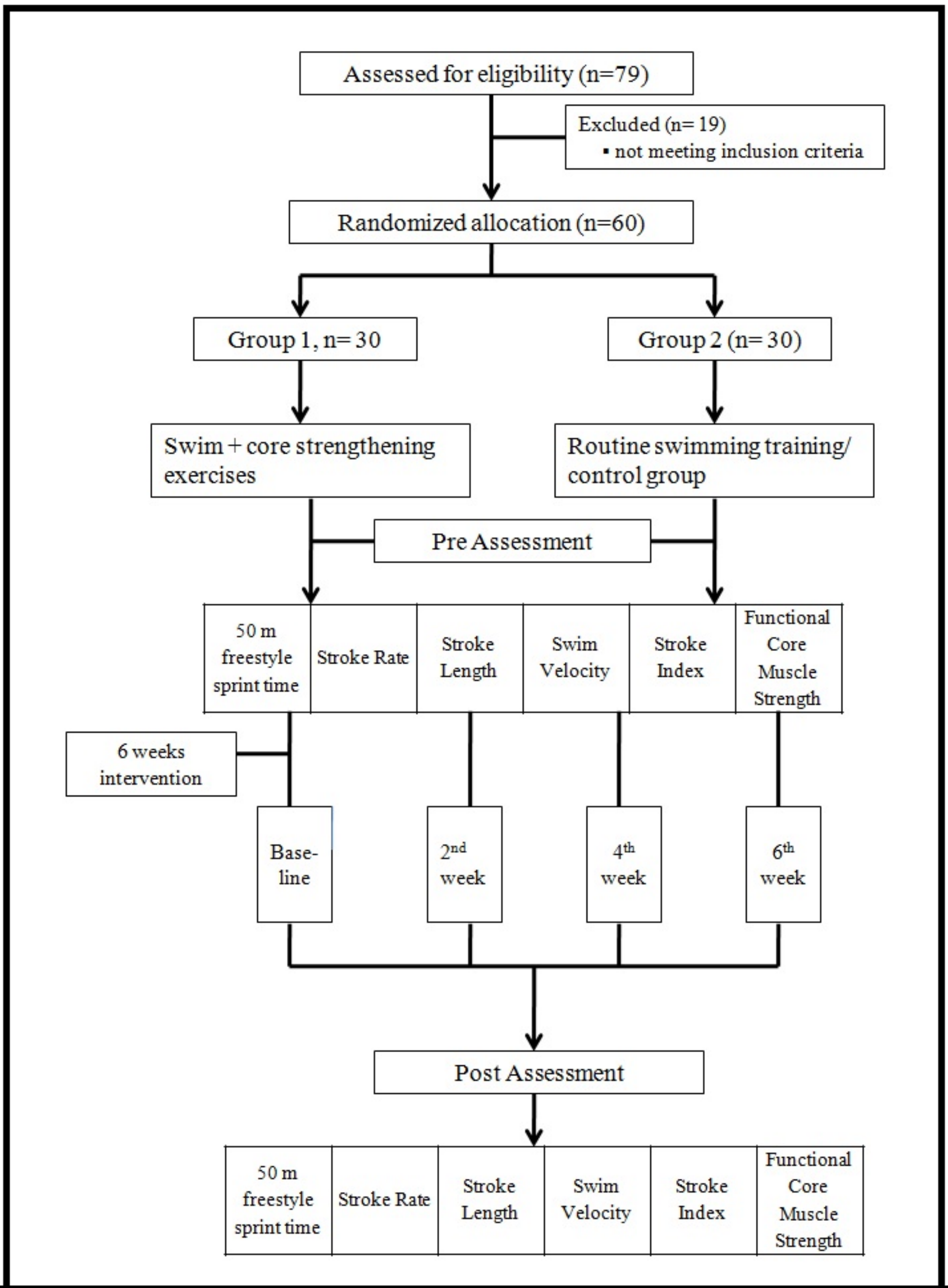

FIGURE 1: Flowchart of the study

Table 1: Demographic Information of the Subjects enrolled in the study

	Descriptive Statistics*			
	Group 1		Group 2	
	M (n=19)	F (n=11)	M (n=19)	F (n=11)
Age	14.7 ± 1.29	13.4 ± 1.50	14.7 ± 1.29	13.4 ± 1.50
BMI	19.97 ± 5.04	21.03 ± 3.08	21.4 ± 2.59	19.78 ± 2.01

Abbreviations: BMI, Body Mass Index; n, Number of subjects
*Data presented as Mean ± SD

Table 2: Mean (± SD) of 50 m Freestyle Sprint time, Stroke Rate, Stroke Length, Velocity, Stroke Index for pre test and post test & percentage change at the end of training from baseline

Table 2	Descriptive statistics for 5m freestyle sprint time, Stroke Rate, Stroke Length, Swim Velocity & Stroke index‡ , Percentage change at the end of training from baseline					
Assessment		**Pre test**	**Post test**			**% change**
			2nd week	4th week	6th week	
50 m freestyle sprint time	Group 1	36.74 (6.76)	36.50 (6.81)	36.18 (6.62)*	35.71 (6.52)*†	2.8
	Group 2	35.76 (4.12)	35.24 (4.49)	35.30 (4.30)	35.33 (4.43)	1.2
SR	Group 1	63.48 (11.28)	62.86 (10.07)	62.69 (10.13)	62.49 (9.23)	1.55
	Group 2	64.50 (9.91)	64.67 (9.11)	63.91 (8.71)	63.70 (7.87)	1.24
SL	Group 1	1.37 (0.37)	1.39 (0.35)	1.41 (0.38)	1.43 (0.37)	4.37
	Group 2	1.35 (0.28)	1.35 (0.26)	1.37 (0.26)*	1.38 (0.26)*	2.22
v	Group 1	1.40 (0.22)	1.41 (0.23)	1.42 (0.23)	1.44(0.23)*	2.85
	Group 2	1.42 (0.16)	1.43 (0.16)	1.43 (0.16)	1.44 (0.18)	1.40
SI	Group 1	2.0 (0.84)	2.05 (0.84)	2.08 (0.85)	2.14(0.88)*	7
	Group 2	1.94 (0.59)	1.97 (0.58)	1.99 (0.58)	2.03. (0.62)	4.63
Abbreviations: SR- Stroke Rate; SL- Stroke Length; SI- Stroke Index; v- swim velocity Group 1: Core training group; Group 2: Control Group						
*significant difference within group between pre and post test by comparing mean differences at p<0.05; †: significant difference between groups by comparing mean difference at p<0.05 ‡: Values are in Mean (±SD)						

Table 3: Mean (± SD) of Functional Core Strength for pre test and post test & percentage change at the end of training from baseline

Table 3	Comparison of Pre test and Post test of Functional Core strength in swimmers					
Assessment		Pre test	Post test			% change
			2nd week	4th week	6th week	
Functional Core strength	Group 1	0.67 (0.76)	0.76 (0.57)	1.73 (1.17)*	2.53 (1.33)*†	73.51
	Group 2	0.67 (0.59)	0.90 (0.73)	0.86 (0.73)	1.03 (0.83)	34.95
***significant difference within group between pre and post test at p<0.05; †: significant difference between groups at p<0.05**						

4. Results

This study enrolled a total of sixty young competitive swimmers. At the baseline there were no significant differences between the groups in age, BMI, or any of the outcome measures.

Demographics of each group are provided in **TABLE 1.** The mean (±SD) for all outcome measures 50m freestyle sprint time, Stroke Rate, Stroke Length, Swim velocity, Stroke Index are summarized in **TABLE 2** and Functional Core Muscle strength test **TABLE 3**

Repeated measures ANOVA analysis of 50 m freestyle sprint time showed significant changes in group 1 ($p < .05$) at the end of fourth and sixth week of training. No differences were found in group 2 ($p > .05$). Post hoc comparison within groups demonstrated a significant difference between baseline and post fourth and sixth week of training. Comparison between group 1 and group 2 for swimming performance using independent student t-test showed significant changes at the end of training period ($p > .05$). No significant differences were obtained between baseline and at the end of training for Stroke Rate and Stroke Length ($p > .05$). However the percentage difference between baseline readings to Post training sixth week reported 1.55% as compared to 1.24% improvement in control group, and for Stroke Length 4.37% improvements in experimental group & 2.22% control Group as shown in **TABLE 2.**

A significant difference was obtained between baseline and post sixth week of training of Swim velocity and Stroke Index ($p < .05$). Post hoc comparison demonstrated significant improvements in swim velocity and stroke index at the end of training. Improvements were shown in the fourth week alone. No significant differences were observed between the groups for swim velocity and stroke index.

A non parametric Friedman's test revealed a statistical significant difference of functional core muscle strength in group 1 (Chi square (3) = 69.191, $p < .05$). Subsequent Mann Whitney U test showed a significant difference between the groups ($p < .05$).

5. Discussion

We hypothesized that a combined swimming with additional core training would improve the swimming performance in young competitive swimmers.

5.1 50 m Freestyle sprint time

The results show that the group 1 improved significantly (p=.000) at the end of training while no change occurred in group 2. Both the groups improved their performances in 50 m freestyle swim timings but the experimental group gained statistically significant higher values than the control group at the end of training ($p < .05$). In a previous study dry land strength training did not reflect the transfer of strength gains into the swim time[28]. On the other hand another study reported enhanced core stability, which did not transfer into improvement of swimming performance[24].

In this study as expected the specific, scheduled and composite core strength training exercises does definitely lead to a greater significant improvement in the sprint time for 50m freestyle swimming. The liable explanation to this could be higher demand on motor system and increased muscle activity by the core muscles which maintained the streamlined posture required while swimming and thus producing powerful movement efficiently, thus improving the swim time.

If the pelvis is unstable the swimmer will not be able to generate maximum power with each kick and stroke thereby increasing the swim time. When the abdominal muscles are not strong enough to balance on water, the trunk tends to sag down laying extra kinematics causing an increased drag which demands on the structure of upper and lower limbs to maintain the state of equilibrium[5]

In comparison of both the groups of this study, the group 1 showed the improvement in performance at the end of fourth week, thus signifying the importance of core strength training in improving the timed performance of young swimmers.

5.2 Stroke Rate, Stroke Length and Swim Velocity

As per statistical analysis there was lack of improvement in performances of stroke rate and stroke length at the end of 6 weeks of core training period in group1, but there was statistically significant difference in stroke index at the end of sixth week (p=.010) and swimming velocity improved as early as at the end of fourth week (p=.000), however, group 2 showed an improvement in swim velocity only at the end of 6th week (p=.003).

This study showed a non significant decrease in stroke rate (average 0.08 stroke min^{-1}) after 6 weeks of core training. Many studies have identified stroke rate and stroke length as a factor of swimming performance and it is associated with muscular power[14]

Increased velocity is accounted for by an increased stroke length and decreased stroke rate, and increase in speed can also be obtained by increased stroke length with no change in stroke rate in freestyle swimmers[6,7]. One study found out that the velocity changes varied between slower and longer competitors, but did not show any changes as far as stroke rate and stroke length were concerned. Also another study reported that stroking parameters for short distance events do not have same influence on anthropometric characteristics[22]. There could be a probable association which needs further research between waist hip ratio and the stroke rate and stroke length. According to our observations females having wider pelvis spend few extra fraction of seconds in "turning time". This definitely warrants evidence.

Stroke index improved in group 1 as it's related to velocity and SL, velocity is significantly improved but not SL; so the stroke index value showed changes because of the significant change in velocity[30]. The swimming velocity represents the product of SR and SL, therefore in order to keep a given velocity; the swimmers generally adopt a combination of SR and SL, which they consider to be the most efficient. Elite swimmers adopt a different combination of these parameters in relation to less experienced ones, being the fact that possibly one of the factors determines their higher performance level leading to direct changes in SI[9]. Concerning regarding SI, which is according to the studies in the literature which suggest a relationship between SI and swimming technical skill and that faster swimmers have higher SI values[21].

5.3 Core Strength

This study showed significant increase in functional core muscle strength at the sixth week (p>.000) which was projected as a significant rise in their performance. Core strengthening leads to an improvement in the stability around the lumbar spine bringing about the biomechanical change enabling a swimmer to move more swiftly in water in an efficient manner. If these elements are not maintained, then resistive forces at the extremities will increase and stroke technique will break down, leading to an inefficient stroke. In our study we have seen increased core strength of a swimmer which has improved the ability to maintain efficient technique thorough out the entire race.

Research stating whether there are any benefits of specific core stability or core strength exercises in activating muscles is limited and conflicting because of the wide variety of data collection methods, exercise techniques and subjects used for analysis. There is not one single exercise that activates and challenges all of the core muscles; therefore, a combination of exercises is required to result in core stability and strength enhancements in an individual[1,15]. When designing a strength program for competitive swimmers, we have taken into consideration of exercises that involve movements that are specific to swimming while challenging the core musculature.

Studies attempting to determine an effect of core strength/stability on athletic performance little support had been identified for a relation to performance[17]. In this study it was made sure that the swimmers perform more functional activity for assessing functional core strength. Many sport-specific training program's fail to include low load motor control training, which has been identified as an essential part of core strength training and improving core stability[15]. Therefore, by performing a well structured and functional program using both low and high load training, improvements should be attained in all the processes contributing to core stability and core strength, thus positively impacting sporting performance[15].

This study showed swim specific exercises lead to an improving the performance in swim time with the improvement in core strength evaluated by Functional Core Muscle Strength Performance test. Margins for improvement in subjects are relatively small for highly conditioned group of athletes. Using a homogenous group of athletes, however, does enable a high level of sensitivity for any improvements to be observed following an intervention program[29].

In summary this study suggest that six weeks of core training significantly improves core muscle strength, 50m freestyle sprint time and stroke index with no variations in stroke rate, and stroke length. Nevertheless the improvement in the group 1 was nearly double as compared with the improvements seen in the group 2. Therefore adding specific exercises to a swimmers strength training program will generally increase the speed and power of a swim stroke and tremendously affect the improvement with respect to swim time.

6. Conclusion

Six week core strengthening with routine swimming is sufficient to improve the 50m freestyle swim performance in time, swim velocity and stroke index much earlier than the group which did not undergo core training program. However six week of core training was not enough to improve the stroke rate and stroke length for 50 m distance in young competitive swimmers.

7. Scope of Future Research

Majority of this research demonstrate the effects of short term core strengthening on sprinting performances. Owing to the current popularity in young individuals for strength and conditioning programs, additional long term strengthening trials should be undertaken to investigate on the stroking characteristics and performances. Also a new paradigm is necessary for highly trained individuals to develop different types of core strength training in to maximize the performances. Inference of this Study can be implemented in young Swimmers to improve their sprinting performance.

8. Acknowledgements

The authors would like to acknowledge the swimmers who dedicated their time and energy to participate in this study. The authors also thank to DY Patil Sports Academy, Nerul and Fr Agnel's Sports complex, Vashi for their assistance and cooperation in the completion of this study.

References

[1] Akuthota V, Nadler SF. Core Strengthening. *Arch Phy med Rehabil*; 2004;85(1): S86-92. http://dx.doi.org/10.1053/j.apmr.2003.12.005
[2] Barbosa T, Keskinen KL, Fernandes R et al. Energy cost and intracyclic variation of the velocity of the centre of mass in butterfly stroke. *Eur J Appl Physiol* 2005;93:519-523. http://dx.doi.org/10.1007/s00421-004-1251-x
[3] Bielec G, Makar P. Variability in swimmers' individual kinematics parameters versus training loads. *Biol Sport*.2010;27:143-147.
[4] Bott C, Farmer L B. H. K. Maximizing core strength and stability training for kayakers. *Human Motion Inc*. 2008
[5] Chek P. Swiss Ball Training For Swimmers. C.H.E.K Institute in San Diego, California
[6] Craig AB Jr, Pendergast DR. Relationships of stroke rate distance per stroke and velocity in swimming. *Med Sci Sports. 1979;11:278-83.*,
[7] Craig AB Jr, Skehan PL, Pawelczyk JA, et al. Velocity, stroke rate, and distance per stroke during elite swimming competition. *Med Sci Sports Exerc*. 1985,17;6; 625-634.
[8] Damsgaard R, Bencke J, Matthiesen G, Petersen JH, Muller J. Body proportions, body composition and pubertal development of children in competitive sports. *Scand J Med Sci Sports* 2001;11: 54–60. http://dx.doi.org/10.1034/j.1600-0838.2001.011001054.x
[9] Dekerle J, Nesi X, Lefevre T, et al. Stroking parameters in front crawl swimming and maximal lactate steady state speed. *Int J Sports Med*. 2005;26:1: 53-58. http://dx.doi.org/10.1055/s-2004-817854.
[10] Erlandson, M.C. et al. Growth and maturation of adolescent female gymnasts, swimmers, and tennis players. *Med Sci Sports Exerc.2008;*40:1: 34-42. http://dx.doi.org/10.1249/mss.0b013e3181596678
[11] Fekete, M. Periodized strength training for sprint kayaking/canoeing. Toronto Island Canoe Club, Toronto. 1998.
[12] Geladas ND, Nassis GP, Pavlicevic S. Somatic *and* physical traits affecting sprint swimming performance in young swimmers. *Int J Sports Med 2005*;*26*:*139*–44. http://dx.doi.org/10.1055/s-2004-817862
[13] Grif Fig: Strength training for swimmers: Training the core, *Natl. Str. Cond. Assoc. J*.2005;27:2: 40-42.
[14] Hellard P, Dekerle. J et.al. Kinematic measures and stroke rate variability in elite female 200-m swimmers in the four swimming techniques: Athens 2004 Olympic Semi-finalist and French National 2004 Championship semi-finalists. *J. Sports Sci*. 2008;26:1: 35-46 http://dx.doi.org/10.1080/02640410701332515.
[15] Hibbs AE, Thompson KG, French D, Wrigley A, Spears I. Optimizing performance by improving core stability and core strength. *Sports Med*. 2008; 38:12: 995-1008. http://dx.doi.org/10.2165/00007256-200838120-00004.
[16] Kibler WB, Press J, Sciascia A. The Role of Core Stability in Athletic Function, Sports medicine 2006:36: 189-198. http://dx.doi.org/10.2165/00007256-200636030-00001
[17] ätt E, Jürimäe J, Haljaste K, et al. Physical Development and Swimming Performance during Biological Maturation in Young Female Swimmers. *Coll. Antropol*, 2009;33: 117-122.
[18] Mackenzie B. 101 performance evaluation tests, in Brian Mackenzie, eds. 2005
[19] Martens J, Einarsson Ingi, Schnizer Nama et al. Lower trunk muscle activity during front crawl swimming in a single leg amputee. *Portuguese Journal of Sport Sciences*, 2011;11: 751-754.
[20] Morouço P. Force production in Tethered Swimming and its relationship with performance. A new approach to evaluate the anaerobic capacity of swimmers? *[thesis]*. University of Porto, Faculty of sport, Portugal. 2009
[21] Pelarigo, Jailton Gregório et al. Technical Indexes Corresponding to the critical Speed and the maximal Speed of 30 minutes in swimmers with different aerobic

performance levels. Rev Bras Med Esporte. 2007; 13:3: 148-152. http://dx.doi.org/10.1590/S1517-86922007000300004.

[22] Pelaya P, Sidney M, Kherif T et.al stroking characteristics in freestyle swimming and relationships with anthropometric characteristics, jr of applied biomechanics, 1996, 12; 197-206.

[23] Salo Dave, Riewald S.A. Training for Core Stability. In *Complete Conditioning for Swimming*. 2008: 87-110. Available at: www.HumanKinteics.com.

[24] Scibek J.S. The effect of core stabilization training on functional performance in swimming. [*Thesis*], University of North Carolina, Chapel Hill. 2001.

[25] SchneiderP, Meyer F. Anthropometric and muscle strength evaluation in prepubescent and pubescent swimmer boys and girls. *Rev Bras Med Esporte*. 2005; 11: 4. http://dx.doi.org/10.1590/S1517-86922005000400001.

[26] Strass D. Effects of maximal strength training on sprint performance of competitive swimmers. In: Swimming Science V. Eds: Ungerechts, B.E., Wilke, K. and Reischle, K. Spon Press, London. 1988; 149-156.

[27] Tanaka H, Costill DL, Thomas R, Fink WJ, Widrick JJ. Dry-land resistance training for competitive swimming. *Med Sci Sports Exerc*. 1993; 25: 952-959. http://dx.doi.org/10.1249/00005768-199308000-00011

[28] Toussaint H.M. Analysis of front-crawl swimming performance factors using the MAD-system: science meets practice. In: P. Hellard, M. Sidney, C. Fauquet & D. Lehénaff (eds.), Proceedings First international symposium sciences and practices in swimming, France: atlantica. 2006: 51-57.

[29] Tse MA, McManus AM, Masters RS. Development and validation of a core endurance intervention program: implications for performance in college-age rowers. *J Strength Cond Res*; 2005;19 :547-52. http://dx.doi.org/10.1519/00124278-200508000-00011

[30] Willardson, J.M. Brief Review Core Stability Training : Applications To Sports Conditioning Programs. *J Strength Cond Res*, 2007; 21: 979-985. http://dx.doi.org/10.1519/00124278-200708000-00054

Authors Profile

Dr. Dnyanesh Patil (P.T): Assistant Professor, Department of Physiotherapy, D.Y Patil University, Nerul, Navi Mumbai. BPTh, MPT (Sports). Working sports Physiotherapist aiming towards developing sports performances and rehabilitation. Research interest in the field of Sports, Especially in swimming.

Dr. Shivani Chowdhury Salian (P.T): Professor, Department of Physiotherapy, D.Y Patil University, Nerul, Navi Mumbai. She is a Research Scholar pursuing at the same university. She also a qualified Professional in Clinical trial Management. She also achieved the Fellowship of the Academy of General Education. She is a Executive Committee Member of Mumbai Branch of IAP and Life Member of IAP. She also has designed instruments like Vaginal Electrode, Perineometer, Pelvic Inclinometer, Pelvic Floor Exerciser. Published and presented research papers in different areas of specialties in physiotherapy. Her a**reas of Special Interest includes** Women's Health and Geriatrics. Ante-natal, Post-natal, and Gynaecological Conditions, Occupational and Environmental Medicine, Exercise Physiology and Sports.

Dr. Sujata Yardi (P.T) is Advisor, Department of Physiotherapy, D Y Patil University, Nerul, Navi Mumbai. Former Dean, Professor and Director of the same Department. She is having 44 years of vast experience in the field of Physiotherapy. She has Published and Presented numerous Research papers. She also has conducted workshops on various topics like EMG and NCV studies, Update on Electrotherapeutics, Vestibular Rehabilitation, BPPV, Recent Trends in Electrotherapy practice, and Recent Advances in Electrotherapy. She also has received Fellowship Award from IAP in the year 2010. Her areas of Special Interest includes Pulmonary and Cardiac Rehabilitation, Orthopaedic Rehabilitation, Adult Neuro-Rehabilitation, EMG and NC studies