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Relationship of physical characteristics, power and swimming time in sprint swimmers

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ABSTRACT

Short distance sprint swimming is a sport which requires production of high intensity force in a relatively short period of time. Thus it depends on the power developed by both the upper and lower limbs, especially in short distance events. On the other hand, swimming performance is a multifactorial phenomenon involving energetics, biomechanics, hydrodynamics, strength parameters and anthropometrics. There are four different style of swimming which have different requirements as per the technique in terms of power and the anthropometric characteristics. The present study evaluated the relationship of physical characteristics, power and swimming time in sprint swimmers. A total of 118 competitive sprint swimmers boys (n=64), girls (n=54) aged 9-17 years, with at least 1 year of swimming experience were chosen. They underwent anthropometric testing followed by power testing of the upper and lower extremities and finally the recording of the 50m sprint swimming time in their respective strokes. In results, statistically significant positive correlations ($p<0.001$) were found between the physical characteristic variables with the upper and lower extremity power and significant negative correlations ($p<0.001$) with swimming time. Also statistically significant negative correlations ($p<0.001$) were found between the swimming time with the upper and lower extremity power. It may be concluded that the physical characteristics were positively correlated with the muscular power and negatively correlated with the swimming time. Also the swimming time was negatively correlated with the muscular power.

Keywords: Physical characteristics. Anthropometric variables. Power. Swimmers.

INTRODUCTION

Power and strength sports require the ability to generate high amount of force in relatively short period of time [12]. The ability of high rate of force development is the central to success in activities that rely on jumping, change of direction, and/or sprinting performance [12]. And swimming is a sport which involves all of these activities. Swimming depends on the power developed by both the upper and the lower limbs, especially in short distance events [6].

Swimming races include elements of a start, turn and clean swimming distance [4]. A study reported that the starting time helped explain 23% of the performance in the male competitors and as much as 40% in female competitors [28]. The time during the start covers almost 25% of the total time needed to swim 25 m and 10% of that needed at the 50 m matches and about 5% in 100m matches [7,19]. Secondly, the performance can also be determined by the turn time resulting in change of direction in the shortest time possible [25]. Turns provide increased propulsion [30]. Thirdly, as the propulsive force generated by the swimmer is, in dynamic equilibrium conditions, the resistance of the water increases geometrically in proportion to the square of velocity. Therefore, a greater ability to generate propulsive force seems to contribute effectively to a better displacement in water [22].

The role of upper limb muscle power is even more essential as 85-90% of the propulsive power comes from the arms and swimming athletes primarily use their arms to generate forward thrust [2,26]. Indeed, one of the studies found only a small contribution of the legs to propulsion (approximately 10%) while another reported only about 15% at Front Crawl [2].

Swimming performance is a multifactorial phenomenon [20]. Swimmers' physical characteristics have been examined to determine the characteristics of successful sprint swimmers [27]. Chronological age of top class athletes indicates the time at which peak performance might be expected and it is lower in case of swimming [17]. It seems that anthropometric characteristics are highly related with young swimmers' performance. For instance, positive correlations between hand and foot size with swimming performance exists [16].

Studies have been conducted to establish the relationship between the muscular power and the swimming time. But, as far our knowledge, there is no literature available which gives a relationship between the physical characteristics and muscle power also taking into consideration the swimming performance, especially in Indian population. For this purpose, this present study aims to find out the relationship between the physical characteristics, power and swimming time in sprint swimmers.

MATERIALS AND METHODS

Subjects

A total of 118 competitive sprint swimmers (64 boys and 54 girls) of 50m and 100m from all four style of swimming i.e. freestyle (n=39), breaststroke (n=28), butterfly (n=23) and backstroke (n=28); aged 9-17 years (mean age ±S.D 13.06 ± 2.55 years) with at least 1 year of competitive swimming experience participated in the study. Out of these, 67 were state level swimmers, 40 were national level swimmers, 3 were international level swimmers and 8 were school level swimmers. Long distance swimmers or swimmers with any knee, back or shoulder injury of past 6 months were excluded. All the participants and their parents or coaches gave their consent for participation in the study. The study was approved by the institutional ethical committee.

Procedure

Anthropometric Testing

The subjects were randomly selected and tested for the anthropometric variables. The age was recorded as the chronological age in years. Standing height was recorded by the anthropometric rod to the nearest 0.2m. Weight was recorded by the standard weighing scale to the nearest 0.5kg. Skinfold measurement was done by the Harpenden skinfold calliper to the nearest 0.2mm. The girths and the diameters were recorded by the flexible measuring tape on the dominant side of the body in centimetres. Chest girth was recorded at the end of normal tidal expiration at the nipple level in males and just below the breasts for females. The lengths were recorded by the anthropometric rod or the small sliding calliper in centimetres. Biacromial and biiliac breadth were recorded by the anthropometric rod in centimetres [27].

Lower Extremity Power Testing

The power of the lower extremity was tested with the countermovement jump test. After the sub maximal trials, the standing reach height was measured to the nearest centimetre. To perform the countermovement jump, the subjects performed the countermovement then extended and jumped as high as possible touching the wall with the hand nearest to the wall. The vertical jump height was recorded in meters and entered into Lewis formula to calculate the power [24].

Upper Extremity Power Testing

The power of the upper extremity was tested with the closed kinetic chain upper extremity stability test. Two pieces of athletic tape (1.5 in width) were placed on the ground parallel to each other 36 in apart for subjects 12 years or older and 24 inches for younger than 12 years. The subject in the push-up position touched the lines by crossing and touching the opposite line. Three trials of 15 seconds were recorded by a standard stopwatch followed by 45 seconds of rest. A power score was then developed [11].

Swimming Time

The subjects performed their usual swimming warm-up routine in the pool before giving the trial. The subjects were then asked to perform a 50m sprint in the pool and the sprint time was recorded by stop-watches manually by two recorders [10].

Statistical Analysis
IBM SPSS (Statistical Package for the Social Sciences) software version 19 was used for statistical analysis. Pearson product-moment correlations were used to examine the correlations between physical characteristics variables, power values and swimming time of all the subjects. A criterion alpha level of $p \leq 0.05$ was used to determine the statistical significance.

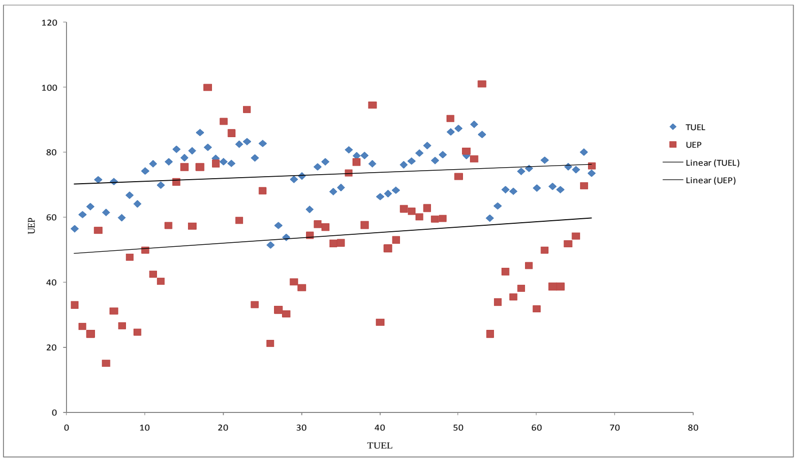
RESULTS

Table 1. Correlation coefficients of physical characteristics with upper extremity power, lower extremity power and swimming time

Variables	UEP		LEP		ST	
	r	p	r	p	r	p
Age (yr)	0.761	0.001	0.791	0.001	-0.586	0.00
HT (cm)	0.819	0.001	0.879	0.001	-0.627	0.001
WT (kg)	0.881	0.001	0.926	0.001	-0.584	0.001
BSK (mm)	0.228	0.013	0.204	0.027	-0.016	0.867
TSK (mm)	0.143	0.122	0.170	0.065	0.104	0.260
SSSK (mm)	0.378	0.001	0.423	0.001	-0.205	0.026
SUSK (mm)	0.366	0.001	0.374	0.001	-0.241	0.008
ABSK (mm)	0.364	0.001	0.318	0.001	-0.108	0.245
AARG (cm)	0.837	0.001	0.862	0.001	-0.560	0.001
AAFG (cm)	0.863	0.001	0.877	0.001	-0.557	0.001
FAG (cm)	0.862	0.001	0.883	0.001	-0.601	0.001
CG (cm)	0.803	0.001	0.861	0.001	-0.540	0.001
GLG (cm)	0.694	0.001	0.654	0.001	-0.452	0.001
THG (cm)	0.773	0.001	0.781	0.001	-0.541	0.001
CFG (cm)	0.835	0.001	0.860	0.001	-0.553	0.001
HED (cm)	0.839	0.001	0.871	0.001	-0.584	0.001
FED (cm)	0.786	0.001	0.814	0.001	-0.530	0.001
FAL (cm)	0.738	0.001	0.808	0.001	-0.586	0.001
HNDL (cm)	0.723	0.001	0.784	0.001	-0.559	0.001
TUEL (cm)	0.748	0.001	0.822	0.001	-0.588	0.001
SHNL (cm)	0.644	0.001	0.698	0.001	-0.509	0.001
FTL (cm)	0.695	0.001	0.766	0.001	-0.592	0.001
TLEL (cm)	0.655	0.001	0.676	0.001	-0.569	0.001
BACB (cm)	0.717	0.001	0.796	0.001	-0.600	0.001
BILB (cm)	0.745	0.001	0.785	0.001	-0.586	0.001

HT= Height, WT= Weight, BSK= Biceps skinfold, TSK= Triceps Skinfold, SSSK= Subscapular skinfold, SUSK= Suprailiac Skinfold, ABSK= Abdominal Skinfold, AARG= Arm relaxed girth, AAFG= Arm flexed girth, FAG= Forearm girth, CG= Chest girth, GLG= Gluteal girth, THG= Thigh girth, CFG= Calf girth, HED=Humerus biepicondylar diameter, FED= Femur biepicondylar diameter, FAL= Forearm length, HNDL= Hand length, TUEL= Total upper extremity length, SHNL= Shank length, FTL= Foot length, TLEL= Total lower extremity length, BACB= Biacromial breadth, BILB= Biiliac breadth.

Figure 1. Relationship of total upper extremity length with upper extremity power



Correlation coefficients of physical characteristics with upper extremity power, lower extremity power and swimming time were shown in Table 1. Highly significant positive correlations (p<0.01) were found between all the physical characteristics with the upper extremity power (except, triceps skinfold) and with the lower extremity power (p< 0.027 - 0.001) (except, triceps skinfold). Statistically significant negative correlations (p< 0.026 - 0.001) were also observed between all the physical characteristics with swimming time (except biceps, triceps and abdominal skinfolds). The relationship of total upper extremity length with upper extremity power was shown in Fig.1.

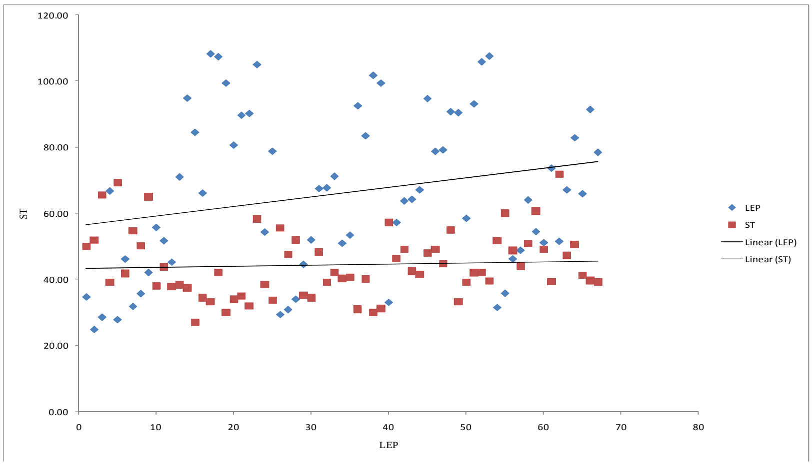
Table 2 showed the correlation coefficients of swimming time with upper and lower extremity power. Statistically significant negative correlations (p<0.001) were noted between the swimming time and upper as well as lower extremity power. The relationship of lower extremity power with swimming time was given in Fig.2.

Table 2. Correlation coefficients of swimming time with upper extremity power and lower extremity power

	UEP		LEP	
	r	p	r	p
ST	-0.642	0.001	-0.621	0.001

UEP= Upper extremity power, LEP= Lower extremity power, ST= Swimming time

Figure 2. Relationship of lower extremity power with swimming time



DISCUSSION

Mechanical power is often referred to as the rate of doing work and is calculated by multiplying force by velocity or the amount of work a muscle can produce per unit of time [12]. The present study correlated the physical characteristics variables with the muscular power and the swimming time thus showing positive correlation of physical characteristics with the upper and lower extremity power (p<0.001) except the triceps skinfold. Therefore, the age also correlated positively with the muscular power (p<0.001). The swimmers in our study were young (9-17 years) and it was seen that swimmers of age group 13-17 years had higher power values on the power testing as compared to the swimmers of age group 9-12 years. Young age and training load led to higher muscular power production in swimmers of the present study. Similar results were seen in the previous studies which found that swimmers had been achieving peak performances in a very younger age [29]. In another study, anaerobic power production was found to be greater in trained pubescent athletes as compared to non-athletes of the same age [15]. These factors supported the positive correlations of age with the muscle power in our study.

The results of the present study showed that girths, diameters, breadths, height, weight and lengths were positively correlated with muscle power (*p*<0.01). Swimmers of the present study performed high intensity short distance swimming sprints; therefore an increase in the value of girths, diameters or breadths resulted in increased power values. Also both male and female swimmers were tall and heavy with long limbs. Taller swimmers performed better on the power testing as compared to shorter swimmers in the present study. Studies had proven that a large cross sectional area of the muscle was presented with increased muscle strength generating characteristics. And, due to skeletal and hormonal maturity during childhood and adolescence, increase in the muscle performance resulted due to muscle related changes in the muscle enzyme activity, an increased proportion of type II fibres etc [18]. According to the same study, pubertal development led to greater muscle mass and force production due to increased height and bone length [18]. On the other hand, short sprint swimming required short bursts of high intensity activity which was further dependent on muscle cross sectional area and fibre distribution according to yet another study [3]. Thus, these results supported the relationship of physical characteristics with muscular power in our study.

The present study showed significant positive correlations (p<0.001) of muscle power with biceps, subscapular, suprailiac and abdominal skinfolds but not with triceps skinfold. It was found that a swimmer who had greater body fat did not always perform better on power tests as compared to a lean swimmer and vice versa. However, according to a previous study, it could be reasoned that the performance in swimming was influenced by the propelling power and in minimizing the resistance to advance in the liquid environment. Thus, physical conditioning of the swimmer, including body fat contributed as well to an extent [23]. Other studies showed that the larger proportion of fat mass in the female swimmers might have allowed the females to kick at a higher rate and thus resulted in greater propulsive efficiency and accounted for a better buoyancy profile of female swimmers than the male swimmers [27]. However, very few literatures are available which reflect the relationship between the body fat content and the muscle power especially in swimmers.

The present study showed a statistically significant negative correlation of the physical characteristics with the swimming time ($p<0.01$). Therefore, age, height, weight and lengths also correlated negatively with the swimming time ($p<0.01$). It was seen that junior age group swimmers (13-17 years) acquired lesser swimming time than sub-junior swimmers (9-12 years); it was mainly due to the effect of physical growth, for example, increased height, and weight and limb lengths. Earlier researches showed both male and female swimmers tended to be taller than the non-athletes of the respective gender. This difference in the stature of swimmers reflected the growth and development of early maturation [23]. Another study showed that the sprint swimmers were taller and heavier than the middle and long-distance swimmers [8]. Increased height resulted in increased longer limbs and thus increased stroke lengths according to a previous study, which decreased the swimming time [1, 9, 21].

The present study showed that the suprailiac skinfold ($p<0.01$) and the subscapular skinfold ($p<0.05$) correlated negatively with the swimming time except the biceps, triceps and abdominal skinfolds. As seen earlier in the present study, more body fat did not affect the swimming performance; in fact it led to a decrease in the swimming time. The age group of the swimmers and the training hours of the swimmers (3-4 hours/day) in the present study might have also led to such a result. According to an earlier research, more than required body fat is an inhibitor of the sporting performance and negatively correlated with the swimming time [23,27]. According to another study, higher buoyancy improved the swimming performance but more in the longer distance events [8]. Also, it was seen in previous studies that the pre-pubertal boys presented higher fat percentile than the pubertal boys and higher skinfold values were observed due to less training load [23].

In the present study, girths, diameters and breadths ($p<0.01$) were negatively correlated with the swimming time. Since swimmers of our study demonstrated muscularity and increased cross-sectional area, it led to greater muscular power and thus decreased swimming time as it would improve the propulsive efficiency. On the other hand, swimmers who had larger bodies demonstrated poor swimming performance in the present study. According to an earlier study, the energy cost was an important determinant in swimming. Energy cost was defined as the energy expenditure per unit of distance [8]. The larger body dimensions were associated with a decrease in buoyancy, increase in drag (active and passive), limited acquisition of water driving abilities, increased energy cost and deterioration in swimming performance [8].

The swimming time in the present study correlated negatively with the upper and lower extremity ($p<0.01$). In our study, the short sprint swimmers translated the increased muscular power in decreased swimming time due to better propulsive efficiency. It was similar to the previous studies which had proven that the upper body power was correlated highly with the swimming time [14]. A number of other studies had emphasised the important role of ‘muscular power’ as a determinant of athletic performance. They also showed high correlations between measures of short-term (<45sec) maximal upper body power and freestyle swimming speed [13]. Swimming performances which required anaerobic power of the legs was influenced by strong dive and turn according to earlier studies [5,27,28]. Thus, these studies supported the relationship of swimming time and muscular power in the present study.

CONCLUSION

The present study concluded that the physical characteristics had a positive association with the upper extremity power, the lower extremity power and a negative association with the swimming time except biceps, triceps and abdominal skinfolds. Thus the present study was useful in determining the strength and conditioning aspects of the swimmers based on their anthropometric and physiological profile. Also swimming time had statistically significant negative correlations with the upper and the lower extremities power. Thus the study helped to understand the young Indian swimming population and also to devise training programs for training their strengths and weaknesses. Hence, the present study concludes that there exists a relationship between physical characteristics, power and swimming time in sprint swimmers.

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