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Swimming speed influence factors contribution research based on biomechanics and fluid mechanics analysis

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ABSTRACT

Swimming is a sport that attach equal importance to endurance and techniques, sound techniques ensures scientific exert, make analysis of swimming techniques from fluid mechanics and biomechanics perspective can put forward more objective suggestions to swimming and make contribution to swimming technical rationality and improvement direction. Due to swimmers suffer gravity and water acting force in swim-in process, how to improve propulsion force and decrease resist force is the purpose of problem research, this paper based on the analysis of swimming process starting technique, propelling technique and turning push off such three technical features, apply fluid mechanics and biomechanics theory to make analysis of swimmers arms stroke propelling effect, leg kick propelling effect and trunk movement propelling effect, make quantitative analysis of biomechanics features in arms stroking process, make qualitative analysis of leg kick and leg drive propelling effect conditions as well as trunk deformed propelling contribution conditions to different swimming way. Through research method, analysis line and research results from this paper, reasonable suggestions and theoretical evidence are put forward to swimming techniques.

Key words: Biomechanics, fluid mechanics, propelling effect, skimming angle, swimming speed

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INTRODUCTION

Swimming is a kind of techniques that floating with its own strength on water and moving forward in water by its own limbs motions, it can be divided into competitive swimming and practical swimming, early swimming mostly is regarded as an important part of nobility children education and soldiers training. International swimming associations has been set up until 1908. In competition, traditional power in world swimming including America, Australia, Germany and France, and our country's competitive swimming level now has already entered into international advanced level.

For swimming features analysis and fluid mechanics and biomechanics research, many people have made great efforts, by which swimming techniques improvements and theory practical application have made increasingly progress; some domestic scholars also put forward their own thoughts and results, among them: Fan Chun-Hua Through reviewing Jiangsu Province male swimmer Wang Xin starting swimming techniques applied effects, summarized effects produced by different starting swimming techniques [1], and according to Wang Xin own features, find out starting techniques that fit for Wang Xin, finally look forward the development trend of grab start in swimming; Yang Chun-Hong Through statistic analysis of whole teams preliminaries and finals reaction time [2, 3], relay time in 2008's national swimming championship meet relay items, find that teams total relay time has obviously improved by comparing with that of 2001, no difference between teams in reaction time, give hints that difference of relay time in different team with different relay level stem from relay techniques scientific researching emphasis as well as specialized training, suggest sports team to adopt bigger start momentum back surrounding arm or backward tilt knee-tuck type relay starting techniques, and take sufficient relay coordinate training [4-7] .

In order to better provide reasonable approach to swimming techniques development, mechanics analysis to swimmers in water is indispensible. This paper on the basis of previous person, apply biomechanics and fluid mechanics principle, make analysis of free stroke and butterfly technical features to provide reasonable suggestions and theoretical evidence for swimming techniques improvements and training process by exploring swimming techniques mechanics principle with research process in this paper.

SWIMMING TECHNICAL MOTIONS BIOMECHANICS ANALYSIS

Swimming speed is influenced by many factors; this paper takes free stroke as an example to analyze the basic factors that affect swimming speed, the influence structure as Fig.1 shows.

No.1 to 34 in Fig.1 are respectively standing for: free stroke speed, water propulsion force and water resist force ratio, limbs motions, body state, upper limb, lower limbs, limbs motions, swim-in speed, body density, pull frequency, pull range, swing frequency, swing range, water resist force, water density, water propulsion force, overwater time, underwater time, shoulder joint flexibility, hip knee ankle angle, hip knee ankle angular speed, form drag, friction resistance, wave resistance, over arm height, arm forward extension speed, palm shape, shoulder elbow wrist angular speed, skin shape, body density, swim-in speed, limbs motions and swim-in angle [4].

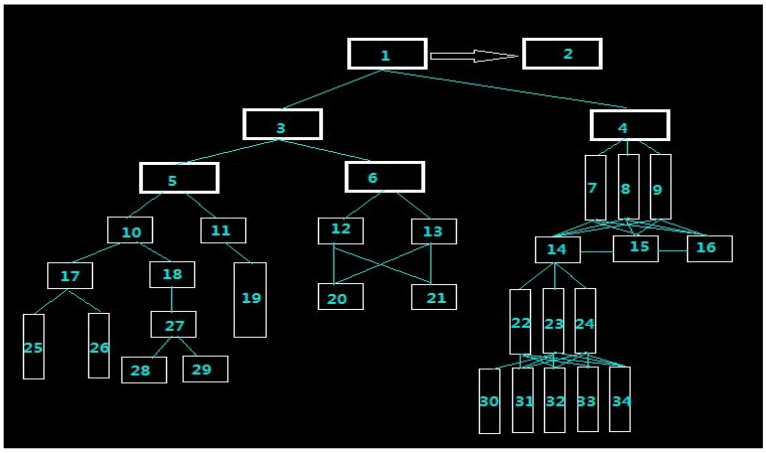

Fig.1: Free stroke swimming speed influence factors structure

Swimming start techniques

In numerous competitive swimming events, expect for backstroke, others as butterfly, frog stroke and free stoke all are starting from start blocks. Swimming start techniques discussed in this paper takes free stroke as an example; describe techniques starting from start blocks.

Swimming techniques that starting from start blocks is mainly divided into swing arm starting motion and grab start motion, from which swing arm start motion is simple, and has big impulse from starting, therefore swimmers soar higher and jump farther, while grab start motion with lower gravity center, gravity center vertical line closer to pool edge, small stable angle tilted to inner pool but good whole stability, therefore the motion enable swimmers to have lower soaring away from blocks and water entering point close to start blocks, more grab start motion adopted in present swimming competitive matches, grab start motions divided into 12 segments as Fig.2 shows, classification of start process is starting from swimmers preliminary postures and ending with underway swimming .

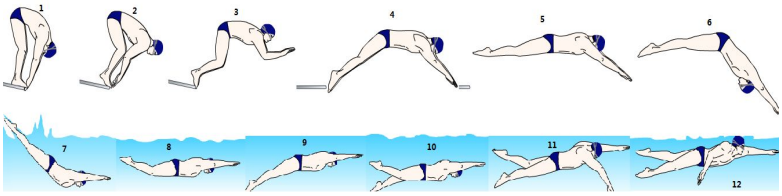

Fig.2: Grab start technical motion schematics

In Fig.2, 1 represents preliminary posture, swimming competitive match begins at 2, use hand onwards pull blocks, body forward extends, with a feeling of being about to drop into water; 3 forcefully push blocks, hands extend out from jaw; 4 arms extend downwards and sight moves downwards when leg off blocks; 5 Spring, that is to jump towards 45 degree direction of front side, and form streamlined in the air: 6when swimmers center arrived the top point, control waist bending; 7 when swim-in, hand entry into water first, try to control hands and legs enter into

water at one point; 8 after body entering into water, swimmers should straight back, body extends forwards; 9 slightly carry out dolphin kick, and meanwhile accelerate speed; 10 before out of water, body should take twice or four times shake kick, head should be lowered and remain body streamlined; 11 make one stroke in water, then float on water, first stroke without breathing after diving in short distance swimming; 12 is the continue actions of 11.

Different grab start techniques have no significant difference in time that spent on the distance moving from blocks to 10meters further, while it has remarkable differences to individual swimmers, that for the distance from hand entry point to pool edge, male swimmers can reach 3.50m as the longest, 3.00m as the shortest, while female swimmers can reach 3.20m as the longest, 2.40m as the shortest.

After swimmers take the water, no matter with which postures, all would be first head surfaced, that is due to human gravity center and buoyancy center not in the straight line after swim-in, buoyancy center in the front while gravity center in the back, then force twist torque forming that let human legs sink and head float, besides human need breathe, head should first surface while considering physiological needs [5].

Swimming propelling techniques:

Swimmers mainly rely on upper limbs stroke motion and lower limbs kick motions to achieve swimming propulsion force, especially arms stroke motion is the main source of propulsion force. Swimming propulsion mechanics main task is discuss lift force and resist force ratios and effect in propulsion force, discuss stroke reasonable route, provide theoretical evidence to swimming technique training in theory.

Resist force formula that water produced to its internal objects as formula (1) shows.

$$D = \frac{1}{2} C_D \rho S v^2 \tag{1}$$

D in formula (1) represents resist force that objects bear; C_D represents resist force index, it has a connection with objects surface smoothness level and is the resist force index of water environment; ρ represents water density; S represents objects project section; v represents objects movements speed. As Fig.3 shows three water resist forces schematic diagram.

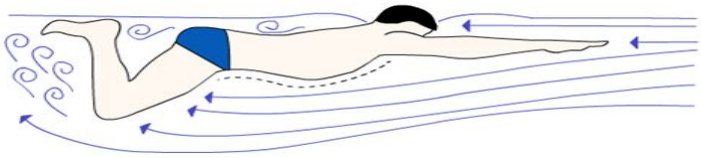

Fig.3: Schematics of 3 water resist forces effects on human

Solid line in Fig.3 represents front resistance, broken line represents friction resistance, and wave represents eddy resistance.

Lift force formula that water produced to its internal objects as formula (2) shows.

$$L = \frac{1}{2} C_L \rho S v^2 \tag{2}$$

Similarly, in formula (2) L represents lift force, C_L represents lift force index. Fig.4 shows that swimmers swim-in along OZ direction, when their hands stroke along V direction, suffer water acting force R ,if breaks down R into vertical lift force L in V direction and resistance D in the opposite direction of V .

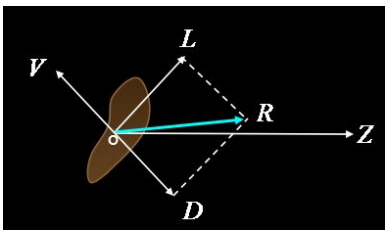

Fig.4: Arms force analysis in swimming process

Hands generated propulsion force conditions within 180 degree that swimmers arms stroking as Fig.5 shows.

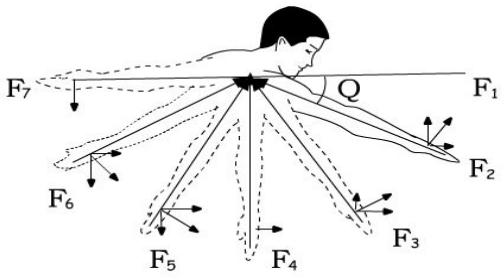

Fig.5: Schematics of hands stroke each time phase propulsion force sizes

Swimming turn techniques

In competitive swimming, every style swimming with more than 100meters distance should take once or many times turn motions, on the condition that well complete turn motion, averagely 0.4seconds can be saved and physical strength can be saved, so merits of turn techniques affect swimming performance to some extent, especially in long distance competitive match.

Under normal condition, swimmers should not reduce speed when close to pool edge and should maintain ongoing momentum so that helpful for completing pike rotation motions; when pike to do rotation, revolve speed can be accelerated and meanwhile make preparation for subsequent pushoff, after ending pushoff, close two arms together and move forward, let head clamp between two arms so as to reduce water resistance. Make motions analysis with breaststroke turn as an example, human state in breaststroke turn important time phase as Fig.6 shows.

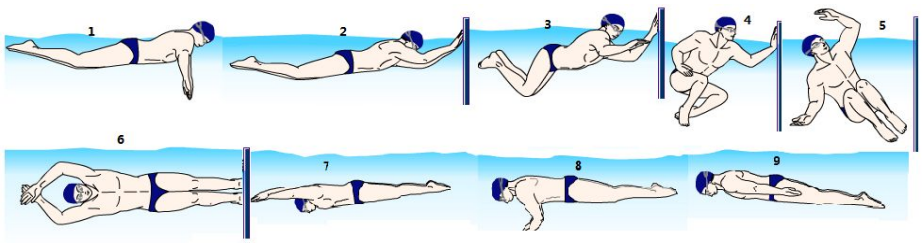

Fig.6: Schematics of breaststroke turn motions

When human upper limbs or lower limbs touch pool edge, human gravity center's momentum would change, human in pike and extend process like a spring first store energy then release, acting process between human and pool edge meet momentum theorem as formula (3) shows.

$$\int f(t)dt = mv_2 - mv_1 \tag{3}$$

Both momentum and impulse are vectors and have their own directions. $f(t)$ in formula(3) acting force from pool edge by lower limbs and pike to human gravity center at t time phase, v_2 is 6 time phase human gravity center speed in Fig.6, v_1 is 2 time phase human gravity center speed in Fig.6.

Swimmers close to pool edge without speed reducing, two hands press pool edge at the same time just like push body, when two hands touch pool edge, one hand quickly off and pull backwards, the other bends elbow so as to bear partial weight, moves away from finger tips and turns one side, tilts and bends knees, as slightly catch, two legs close to pool edge, legs cross from the bottom of upper body, hands push away from pool edge, hands bend highly and surface and move arms, hands and head take the water at the same time, head quickly comes back, palms in hands push out upwards, when legs are vertical to pool edge, body should try to form one straight line when touching, two hands put on the hand, fast and powerfully kick away from pool edge.

SWIMMERS LIMBS SEGMENTS FLUID MECHANICS ANALYSIS

Hands stroke biomechanics quantitative analysis:

Hands lift force index and resistance index is the base for deeper discussion of swimming stroke mechanics, based on which stroke propulsion force nature can be discussed, which is also the ratios of lift force and resistance occupied in stroke propulsion force, this chapter makes research from stroke route and propulsion force types two aspects.

Swimmers hands underwater stroke route is a complicated space curve, that can be regarded as inward, outward, upward, downward, forward, backward such six directions, the previous 4 movements is called as horizontal stroke while the last two is vertical stroke, therefore stroke speed direction can be described by the included angle between stroke speed and horizontal stroke speed, because stroke speed direction is the tangential direction that stroke route located in such point, so above included angle can be used to describe stroke route.

From 2D plane, it can be acknowledged that included angle between stroke speed and horizontal stroke speed which is the included angle β between stroke speed and human horizontal axis as Fig.7 shows. When $\beta = 90^{O}$,it is full vertical stroke in line backwards， when $\beta = 0^{O}$,it is full horizontal stroke, when $\beta \in (0^{O}, 90^{O})$, stroke route is curve stroke both in horizontal and vertical, the smaller the angle is, the more crooked the curve would be, therefore the angle reflects stroke route's crook and straight level.

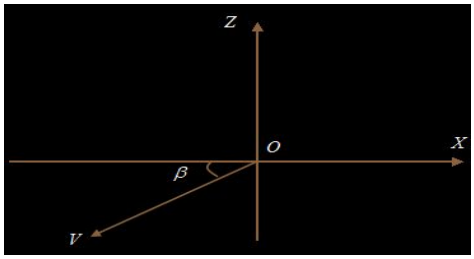

Fig.7: Schematics of included angle between stroke speed and horizontal stroke speed

In Fig.7, Z axis direction is swim-in direction, X axis is human frontal axis.

From force direction, The straight line backwards full vertical stroke when $\beta = 90^{O}$, it is resistance function as propulsion force; full horizontal stroke when $\beta = 0^{O}$, it is lift force function as propulsion force, while curve stroke when $\beta \in (0^{O}, 90^{O})$, it is lift force and resistance composed into propulsion force, the composition of stroke propulsion force in above 3 conditions as Fig.8 shows.

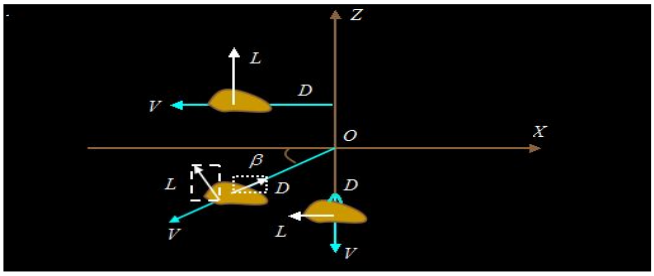

Fig.8: Schematics of different directions strokes' hands force condition

Table 1 and Table 2 show different β angles corresponding lift force and resistance percentage occupy on total propulsion force when skimming angle reach 0 degree and 180 degree.

Table 1: Table of different β angle corresponding lift force and resistance ratio at 0 degree skimming angle

β	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
D	100	95	80	72	66	60	49	44	40	36	32	25	16	13	10	8	5	2	0
L	0	5	20	28	34	40	51	56	60	64	68	75	84	87	90	92	95	98	100
Note：Unit of row β is(°)；row D and L are respectively such two percentage in propulsion force(%).																			

Table 2: Table of different β angle corresponding lift force and resistance ratio at 180 degree skimming angle

β	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
D	100	94	83	76	70	65	60	55	50	46	42	11	9	8	6	5	3	1	0
L	0	6	17	24	30	35	40	45	50	54	58	89	9	92	94	95	97	99	100
Note：Unit of row β is(°)；row D and L are respectively such two percentage in propulsion force(%).																			

Legs kick motion fluid mechanics qualitative analysis:

Due to fluid mechanics test of legs lift force and resistance index haven't been made until now, quantitative research on its kick and drive propulsion force could not be made, only simple qualitative analysis according to ankle joint sports trajectory effects on lift force and resistance in kicking can be made.

As Fig.9 shows, ankle joint force conditions and ankle joint free stroke kick motions ankle joint trajectory conditions in free stroke legs kicking process.

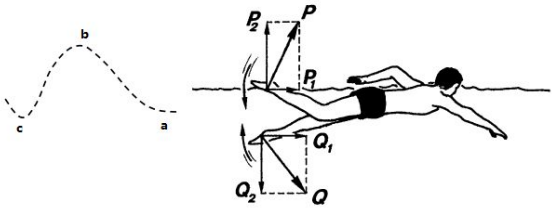

Fig.9: Ankle joint force condition and ankle joint sports trajectory in free stroke legs kicking process

In swimming process, legs movements can produce bigger fluid force that arms movements, however, due to foot and shank's orientation have connections with flow and sports direction, such higher fluid force mainly act on vertical direction, only a little part acting force moves forward along sports direction, therefore legs kick produce effective propulsion force than that from arms stroke, propulsion force produced by legs in free stroke and backwards stroke nearly occupies 15% of total propulsion force, being 20%-25% in butterfly, but breaststroke legs produced propulsion force and hands propulsion force share the same proportion of total propulsion force. Ankle joint sports trajectory in breaststroke kick motions shown in Fig.10, from a to b is breaststroke draw back legs and toss foot motions ankle joint trajectory, foot is moving forward, draw back legs motion increase swimmers water resistance and is harmful for boy forward movements, from b to c is kick motion ankle joint trajectory, feet moves back and down, and roughly in same range of backwards and downwards; lift force and resistance in breaststroke process may become kick propulsion force, since ignored outside and inside two horizontal movements in kicking, feet lift force and resistance index is unknown, therefore only qualitative analysis can be made to propulsion force.

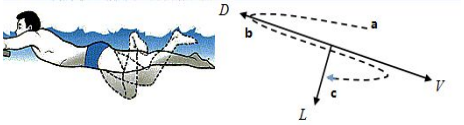

Fig.10: Breaststroke kick motion ankle joint sports trajectory

The most effective legs kick way in swimming is make full use of all joints movement, legs kick through knee joint flexion and extension has an advantage over straight legs kick, which is similar to arms stroke with elbow and wrist

joint flexion better than straight arms stroke, normally when knee joint takes second extensions, maximum propulsion force by legs kick in period can be recorded. With the increasing of swimming speed, it's more effective to make kick motions with decreased range and quicker kick frequency which can provide higher speed in mutual action between feet and flow, reduce opposite direction resistance and legs recovery inertial force.

Role analysis of human trunk in swimming:
Swimmers body has great effect on the generation of hydraulic resistance, so, body "deformed" has great significance to swimming. In order to reduce hydraulic resistance and transfer segments acting force and change its shape and rigid ability, swimmers make ups and downs motion in butterfly and breaststroke, their trunk can direct make contribution to propulsion force; In free stroke and backwards stroke, trunk rotates along its vertical axis that is helpful for swimmers to make use of huge powerful back, pectoral muscle groups so as to increase muscle tone and fluid reverse acting force, this rotation is helpful for arms opposite direction recovery on water surface, and decrease arms horizontal movements.

CONCLUSION

This paper explored swimming technical issues from biomechanics and fluid mechanics perspectives, first made analysis of swimming technical motions, successively analyzed swimming start techniques, swimming propelling techniques and swimming turn techniques, got three motion segments technical features and biomechanics characteristics, then analyzed hands, legs and trunk such 3 body part influence conditions with swimming propulsion techniques in propulsion technique aspect, put forward reasonable suggestions to improve swimming propulsion force. It focused on research of hands effect to swimming propulsion force, discussed that corresponding resistance and lift force proportion to total propulsion force under different skimming angles β angle changes; made qualitative analysis of legs kick and drive's ankle sport trajectory status, achieved reasonable legs kick suggestions; described trunk "deformed" contributions to different swimming ways propulsion force.

REFERENCES

[1] Fan Chun-Hua. *Teaching of Forestry Region*, **2012**，(10)，102-103.
[2] Yang Chun-Hong. *Zhejiang Sport Science*, **2010**, 32(2)，97-100.
[3] Tian Jiao-Yu. *Journal of Shandong sports institution*, **2013**, 29(6), 76-80.
[4] Xu Jian-Fang. *Chinese sports science and technology*, **2010**, 46(6), 69-72.
[5] Zhang B.. *Int. J. Appl. Math. Stat.*, **2013**, 44(14), 422-430.
[6] Zhang B., Zhang S. and Lu G.. *Journal of Chemical and Pharmaceutical Research*, **2013**, 5(9), 256-262.
[7] Zhang B., Yue H.. *Int. J. Appl. Math. Stat.*, **2013**, 40(10), 469-476.