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Swimming techniques quantitative analysis research based on grey relational degree model

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ABSTRACT

With swimming training levels constantly improvement requirements and sport training test apparatus gradually perfection, sport training will gradually move towards quantification. Rey system theory relational degree analysis will be more widely applied in sport training. The paper mainly researches swimming technical training, makes quantitative analysis of swimming important event relay technique, finally uses grey relational degree analysis researching its application in swimming training. It gets that insufficient technical training volumes and old technical training means are the causes that lead to Chinese swimming level backward. Therefore, it not only should focus on research and improve training methods, but also should research technical motions rationality and efficiency.

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KEYWORDS

Swimming technique;
Relay technique;
Quantitative analysis;
Grey relational degree.

INTRODUCTION

Since implementing open and reform for more than 30 years, China has ushered in sports leap development, sports level has been obviously improved that achieved excellent results in lots of international competitions. From 1984 Olympic Games 15 gold medals achievement to 2008 Olympic Games 51 gold medals, 21 silver medals and 28 bronze medals historic best performance, China has surpassed America and dominated top one in gold medal tally. In 2012 London Olympic Games, China achieved 38 gold medals, 27 silver medals, 23 bronze medals, which ranked in second both in gold medal tally and overall medal table, and created best performance in participating Olympic Games overseas. From 2008 to 2012, not only complete Chinese competitive sports roosting dream in

Olympic Games, but also realize competitive sports several decades long-cherished wish, meanwhile it is also best proof of Chinese “Program of Striving for Olympic Glory” and “All-state system” and other policies reflective results.

Historic breakthrough in gold medal, though it reflects we have already gone into a great sports nation era, we still have a long way to go to become genuine sports power. “Persons in the world of athletics and swimming”, it is a famous word in Olympic Games, which fully explains competitive swimming event, has an important position in Olympic Games. But competitive swimming event is still China’s weak event; it seriously hinders China moving into the circle of sports power. In 2000 Sydney Olympic Games, Chinese swimming event came away with nothing, while in 2004, 2008 two sessions Olympic Games, it also just achieved one gold

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medal; In 2012 Olympic Games, Ye Shi-Wen achieved women 400m medley swimming champion and broke through world record, Sun Yang achieved men 400m free stroke champion and men 1500m free stroke champion that also broke through world record. Swimming performance improvement is inseparable from swimming training rules constantly understanding. Chinese swimming training by several decades exploring, it forms its own theory and method system, and achieves great performance. Current world competitive swimming training appears new theory and moving direction, new techniques and methods that effect Chinese competitive swimming training theories and methods.

SWIMMING TECHNICAL TRAINING DEVELOPMENT

American scientific researchers researching on Olympic Games finals and preliminary contests show that athletes enter into finals and athletes in preliminary contests have no obvious differences in strength, the differences are final athletes has small resistance and high technical efficiency. With regard to that, lots of experts think that swimming is a kind of sport majoring in technology-driven, swimming technical training should become main training contents not load adjustment transformation means, time and energy that take in technique aspect should be the same on that of improving strength and endurance, or even more^[1].

Insufficient technical training volumes and old technical training means are one of reasons that cause Chinese swimmers techniques relative rough^[1]. Excellent swimmers technical training have already not been general technical exercises or adjustment means, but it is established in improving technical efficiency. Chinese famous coach Zhang Ya-Dong thought that in the aspect of technical training, it should targeted athletes different training phases detailed situations, by adjusting motions frequency and motions effects to improve technical levels and qualities, so that improve sport performance. It is clear that coaches should be adept in applying strong targeted and good efficiency technical training methods, and should highlight technical individualism to excellent athletes' technical training.

From 1970s majoring in strength exercising to present reducing resistance, improving efficiency train-

ing, it essentially is training guidance ideas great change, which is also the result of continuous deepen understanding on swimming and swimming training. Focus on technical training, not just as simple as adding technical training, the importance is technical training ways and methods constantly innovation, promoting athletes individual technical efficiency constantly improving^[2].

From the 26th Olympic Games to 27th Olympic Games, from the 27th Olympic Games to 2001 Fukuoka world swimming championship as well as 2003 Barcelona world swimming championship, swimming event sports performance shows large area, large amplitude, short time improving features, swimming performance improvement, especially for free stroke, butterfly, breaststroke performance improvement, one important reason of them is swimming technical development^[3].

Swimming performance is up to physical ability and technique two parts, physical ability is base, technique is guarantee, technical training and physical training complement each other, neither of them can be dispensed with. Researches show that Olympic Games swimming competition top eight compares with athletes haven't entered into finals; the difference is not in stroke strength but in technique, the former more trends to streamline than the later^[4,5]. Russian scientific researchers call swimming as "is a kind of sport combining biomechanics with physiology, biomechanical efficiency is the most important factor of swimmers success". Australian coaches thought that swimming is a kind of technology-driven sport. Russian famous coach Touretski went to Australia, and then brought in the training idea "improve efficiency and reduce resistance by improving techniques". Hereby, Australian swimming scientific researchers based on Russian competition technical analysis method, they developed a set of competition technical analytic system, during domestic and international major competitions, collected lots of data information, by analyzing and researching, they summarized ideal techniques six main elements that let Australia achieved great success in the 27th Olympic Games swimming competitions. Some Chinese coaches seen that foreign partial excellent athletes completion training intensity was very high, and so they thought Chinese athletes gap existed on intensity^[6]. On the surface, Chinese athletes gap is intensity, but actually Chinese ath-

letes gap is capacity of keeping correct techniques. In recent years, coaches and athletes really understand technique importance to swimming.

By scientific research and sports practice, swimming techniques and training methods are constantly reforming and innovating, which let swimming performance constantly improve and swimming new records emergent. Chinese swimming has also many successful experiences, in 1950s, 1960s, Chinese swimmers broke through world records for many times, which just got profits from technical innovation. But, from overall understanding, our understanding to swimming essence and technical efficiency to sports performance importance still have certain one-sidedness and deviation, and insufficient theoretical understanding on the contrary also restricts advanced technical understanding, accepting and mastering. Therefore, technical training scientification is a priority of all current Chinese swimming training.

SWIMMING TECHNICAL TERMS AND PARAMETERS DEFINITION

Streamline concept

In swimming marching whole process, it should focus on always keeping body streamline; swimming streamline refers to “flat, straight, sharp, tight, and high”. Swimming should always put improving stroke efficiency and reducing resistance into first place, reducing resistance also means always keeping body streamline in whole swimming process. Flat, is body position, which is to keep better body position by hands positively forward extending and kicking, especially good kicking capacity is the base of keeping better body position. $F=C_pSV^2$, from which: C is resistance coefficient, ρ is fluid density, S is cross section area, V is speed. It can vividly compare to: C requires “sharp”, “tight”, “slip”, S requires “flat” and “high”.

Acting force and reaction force concepts

Swimming main propulsion source is acting force and reaction force——resistance. Previous opinions thought that swimming propulsion main source is lift force. Current opinions think that it mainly is acting force and reaction force, which is also forward resistance from water. The concept change brings into greatly change on stroke routine. For example, free stroke arms pull

technique, to let arms pulling generate maximum propulsion and better playing muscle strength, it requires arms stroke point should be slightly wider than shoulder when stroking in front of shoulder, have the equal width when stroking to beneath the shoulder, and narrower than shoulder when swimming through shoulder, the whole free stroke's stroke routine is a small “S” type, “S type” should be obviously smaller than previous concept, free stroke's stroke motion should be forward extending, wrist flexing, elbow bending, small external stroking, big internal stroking, and final lifting elbow and stroking upwards then completing whole stroke motions.

Balance concept

Hands and legs cooperation is best tool to keep body balance in the water. We call body part as work platform; it is body exertion center and also body balance point. Hands, legs and head are body balance tools; the purpose is to let body keep balance in the water, which is also trying to let gravity center point and buoyancy point get closer. Body balance includes keep better body position in the water by hands, waist, and legs coordination and cooperation.

RELAY TECHNICAL RESEARCH

In the 27th Olympic Games swimming competition relay event, Chinese women team three relay events all went into finals, seen from competition results, Chinese women relay athletes relay techniques basically arrived at world level. For women $4 \times 100m$ medley swimming relay event, Luo Xue-Juan relay time was 0.27s, Zhou Ya-Fei 0.22s, Zhu Yin-Wen 0.08s, for women $4 \times 200m$ free stroke relay event, Xu Yan-Wei relay time was 0.28s, Yang Yu 0.18s, Pang Jia-Yin 0.26s, for women free stroke relay event, Xu Yan-Wei relay time was 0.24s, Yang Yu 0.18s, Zhu Yin-Wen 0.44s (TABLE 1, TABLE 2), from which only Zhu Yin-Wen in free stroke relay last step relay time was slower (correlated to performance result).

The 10th world swimming championship, Chinese men, women swimming relay teams relay time:

Women $4 \times 200m$ free stroke:

Preliminary contest $0.27+0.27+0.41=0.95s$

Finals $0.25+0.32+0.30=0.87s$

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TABLE 1 : The 27th Olympic Games swimming competition finals Chinese women relay team athletes' relay time table

Event	4×100m Medley swimming relay		4×200m free stroke relay		4×100m free stroke relay	
	Athlete	Relay time(s)	Athlete	Relay time(s)	Athlete	Relay time(s)
First relay	Luo Xue-Juan	0.27	Xu Yan-Wei	0.28	Xu Yan-Wei	0.24
Second relay	Zhou Ya-Fei	0.22	Yang Yu	0.18	Yang Yu	0.18
Third relay	Zhu Yin-Wen	0.08	Pang Jia-Yin	0.26	Zhu Yin-Wen	0.44
Total time(s)		0.57		0.72		0.86
Top eight ranking		1		2		7

TABLE 2 : The 27th Olympic Games swimming competition Chinese men, women relay team relaying completion status table

Gender	Competition event	Preliminary contest & finals	Ranking	Total relay time(s)	Relay ranking
Women	4×100m medley swimming relay	Finals	4	0.57	1
Women	4×200m free stroke relay	Finals	2	0.72	2
Women	4×100m free stroke relay	Finals	8	0.86	7
Women	4×100m free stroke relay	Preliminary contest	8	0.91	11
Women	4×100m medley swimming relay	Preliminary contest	5	0.94	12
Women	4×200m free stroke relay	Preliminary contest	6	1.14	13
Men	4×100m free stroke relay	Preliminary contest	15	1.11	15
Men	4×200m free stroke relay	Preliminary contest	10	1.38	16

Women 4×200m free stroke:

Preliminary contest $0.31+0.50+0.29=1.10s$

Finals $0.10+0.22+0.13=0.45s$

Women 4×200m medley swimming:

Preliminary contest $0.21+0.10+0.24=0.55s$

Finals $0.10+0.23+0.13=0.45s$

From Chinese women swimming team performance in world championship, it is clear that best relay performance and worst relay performance have 0.65s gap, the best is during women 4×200m medley swimming finals, last three relay athletes relay performance sum is 0.45s and achieve champion; the worst is during women 4×200m free stroke preliminary contest, last three relay

athletes relay performance sum is 1.10s. So, Chinese women team relay technique is not stable which needs to further improve stability.

By TABLE 3, it is clear that Chinese women relay events compare with world level; the best relay performance has no big gap with world level. If see from ideal relay performance, three relay athletes relay time should be around 0.10s, relay performance sum is 0.30s.

Men 4×200m free stroke:

Preliminary contest $0.39+0.18+0.31=0.88s$

Men 4×200m free stroke:

Preliminary contest $0.10+0.16+0.40=0.66s$

Finals $0.19+0.32+0.31=0.82s$

TABLE 3 : The 10th world swimming championship women three relay events finals each team time ranking status

Ranking	4×100m medley swimming finals		4×100m free stroke finals		4×200m free stroke finals	
	Country	Relay time(s)	Country	Relay time(s)	Country	Relay time(s)
1	Britain	0.39	Sweden	0.66	China	0.76
2	Sweden	0.44	Britain	0.68	Netherlands	0.79
3	China	0.45	Netherlands	0.78	Australia	0.83
4	America	0.54	America	0.80	Canada	0.83
5	Japan	0.77	Germany	0.84	Sweden	0.84
6	Australia	0.84	China	0.87	Spain	0.85
7	Netherlands	0.84	Italy	0.98	Britain	0.87
8	Germany	0.92	Australia	1.02	America	0.90

Men $4 \times 200m$ medley swimming:

Preliminary contest $0.20+0.21+0.35=0.76s$

From TABLE 4 Chinese men swimming team performance in world championship, best relay performance and worst relay performance have 0.22s gap, the best is during men $4 \times 200m$ free stroke preliminary contest, last three relay athletes relay performances sum is 0.66s, the worst relay performances sum is 0.88s.

Chinese men relay event compares with world level, men free stroke relay time ranks in the fifth, $4 \times 200m$ medley swimming relay time (only has preliminary performance) can rank the eighth, $4 \times 200m$ free stroke relay's relay time (only has preliminary performance) can rank the eighth, best relay performance still keeps paces with world level (TABLE 4). For British team, its $4 \times 200m$ medley time is $0.07+0.05+0.11=0.23s$, for American men $4 \times 200m$ medley swimming, relay time in finals is $0.29-0.02+0.09=0.36s$, Japanese men $4 \times 200m$ medley swimming relay team relay time in finals is $0.16+0.12+0.10=0.38s$.

In addition, presently lots of countries, in starting block, athletes adopt wind-up relay technique, the technique fully achieves larger departing speed from starting block that is very beneficial, while Chinese athletes still adopt grab relay technique, on this point, Chinese athletes relay techniques still need to be further improved

and enhanced.

GREY RELATIONAL DEGREE ANALYSIS AND APPLICATION

In swimming training system, we can get athletes body shape, function aspects data, but it cannot exactly know athletes genetic factor, excitement in some time, psychological state and so on information. Such partial clear, partial unclear information system is grey system. Relational degree analysis as grey system theory put forward one kind of system analysis method, it is a method measuring factors relational degree mainly according to system internal several factors development trend. The factors analysis essentially is analyzing and comparing with grey system several relative sequences and their curves followed time changes. Curve geometric shape gets closer, and then development trend gets closer, relational degree also gets bigger. Due to relational degree analysis makes analysis according to development trends, therefore it hasn't many requirements on samples quantities, and also has no need of typical distribution rules.

Competitive swimming technical features are arms and legs stroking, kicking, driving by turns; upper, lower limbs coordination and cooperation generates forward

TABLE 4 : The 10th world swimming championship men's three relay events finals each team relay time ranking status

Ranking	$4 \times 200m$ medley swimming finals		$4 \times 200m$ free stroke finals		$4 \times 200m$ free stroke finals	
	Country	Relay time(s)	Country	Relay time(s)	Country	Relay time(s)
1	Britain	0.23	Italy	0.38	America	0.36
2	America	0.35	America	0.54	Australia	0.59
3	Japan	0.38	France	0.55	Canada	0.61
4	France	0.54	Germany	0.55	Germany	0.77
5	Netherlands	0.56	Australia	0.56	China	0.82
6	Canada	0.68	Russia	0.58	Britain	0.85
7	Ukraine	0.75	Canada	0.65	Greece	0.86
8	Russia	0.90	Russia	0.91	Italy	1.19
	China	0.76	China	0.88		

TABLE 5 : Original data

	June,2011	January,2012	June,2012	January,2013	June,2013	January,2014
y_0 (50 meters free stroke cooperation)	38'5	36'2	34'1	31'3	29'4	27'6
y_1 (50 meters free stroke kicking)	56''	53'5	51'1	48'8	47'6	45'2
y_2 (50 meters free stroke arm stroking)	45'1	43'3	40'5	36''	33'6	31'2

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propulsion, during marching process, upper, lower limbs are mutually promoting and restricting. In order to find out arms motions and legs motions as well as speed relations, the paper randomly samples five men athletes 50m free stroke relative data (refer to TABLE 5) to

make relational degree analysis.

And then the paper initializes with original data, result refers to TABLE 6.

And then calculate reference sequence and comparison sequence absolute difference, result is as fol-

TABLE 6 : Initialized result

	1	2	3	4	5	6
$x_0(p)$ reference sequence	1	0.927	0.892	0.811	0.776	0.714
$x_1(p)$ comparison sequence	1	0.958	0.915	0.868	0.851	0.832
$x_2(p)$ comparison sequence	1	0.962	0.892	0.793	0.754	0.748

TABLE 7 : Reference sequence and comparison sequence absolute difference

	1	2	3	4	5	6
Δ_{01}	0	0.031	0.025	0.057	0.073	0.118
Δ_{02}	0	0.036	0.001	0.013	0.024	0.036

lowing TABLE 7.

as $\Delta(\min) = 0, \Delta(\max) = 0.118$.

By

$$\varepsilon_{ot}(P) = \frac{\Delta(\min) + \beta\Delta(\max)}{\Delta_{ot}(P) + \beta\Delta(\max)}$$

it solves correlation coefficient is

$$\varepsilon_{01} = (1, 0.694, 0.73, 0.551, 0.478, 0.376)$$

$$\varepsilon_{02} = (1, 0.664, 0.987, 0.834, 0.756, 0.663)$$

By $r_{ot} = \frac{1}{n} \sum_{p=1}^n \varepsilon_{ot}(P)$, it gets relational degree

is $r_{01} = 0.637, r_{02} = 0.818$. Thereupon, arm stroking and cooperation relational degree is larger than that of kicking and cooperation. It shows arm stroking is the closest factor to cooperated development trend.

According to exercise physiology theory, athletes master sports techniques, essentially is temporary neural connection establishing. Long-term, repeatedly exercises will make the neural connection firm and form into a kind of dynamic stereotype. Therefore, to make relational degree analysis of a athlete technical state development change, is already not making analysis of a stack of scattering data but dynamical quantitative analyzing a gradually forming into dynamic stereotype sports technical status. These quantities reflect athletes' tech-

nical compositions each factor relative stable relations.

According to expert qualitative analysis and research and our relational degree analysis of several athletes' 50m free stroke cooperation, arm stroking and kicking techniques, it proves: when $r_{01} > r_{02}$, athletes' technical structures are normal, on the contrary, it is unreasonable. Therefore, to technical structure unreasonable athletes, they should make great technical improvements. And then the paper makes relational analysis of technical normal and unreasonable athletes' track testing data, which provides basis for coaches' timely learning athletes' technical development direction.

Relational degree analysis provides quantitative analysis for swimming technical criterion. The paper analyzes 50 men athletes, it gets 50m free stroke second class technical criterion: $r_{01} \geq 0.58 (S = 0.049)$, $r_{02} = 0.79 (S = 0.043)$. In this way, during swimming training, except for speed quantity criterion, it also gets technical quantization criterion. If making technical structure relational analysis of all four kinds of swimming patterns and different distances, different levels men and women athletes' on the larger samples basis, then the paper can establish a complete swimming technical criterion system. Use these technical standard to analyze and measure athletes technical state, achieved results will become coaches technical training moment evidence, so that play important roles in training.

CONCLUSIONS

Swimming training system is a grey system; the paper applies relational degree analysis method analyzing swimming techniques. The analysis method achieves

remarkable results in swimming training further deepen application, which proves grey system theory applying into swimming training is feasible. It finds out a channel for us bringing into quantitative analysis in swimming technical analyses. With swimming level constantly improvements requirements and sport training test equipment gradually perfecting, sports training will gradually move towards quantification. Grey system theory relational degree analysis will be more widely applied in sports training.

Technical training and water strength training are Chinese swimming training weak links, though reflects that it keeps certain paces with foreign countries in training proportions and training means and methods, essentially is our cognition backwardness. Strengthen international exchange and learning, change training ideas; it will enable a breakthrough and innovation. Chinese swimming balance status shows that China hasn't paid enough attention to training balance problems, which causes training structure short of rationality and effects on training overall effects.

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