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MEMS Sensors Applied in Finswimming Movement Analysis

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ABSTRACT. *The purpose of this study aimed to use the measurement of Micro Electro Mechanical systems (MEMS) sensors to analyze the actions of finswimming for 50 meters. The analysis of the major sports limbs acceleration and angular velocity differences between elite and sub-elite athlete. Research method: Use of three-axis MEMS acceleration and gyroscope. Take three elite athlete with three sub-elite athlete, swim in a 50-meter movement of actions of the main four limbs of acceleration and angular velocity data for statistical analysis. The findings of this study are: 1.This paper presents the use of the FFT to calculate the swing frequency, swing frequency FFT calculation there are faster and more accurate results; 2.Triaxial angular velocity of the Y-axis value is the most evident, there are no significant differences only with their own another tri; 3. Triaxial acceleration value to the Z-axis is most evident, there are significant differences in elite athlete group and sub-elite athlete group; and 4. Elite athletes group is better than sub-elite athlete group by 20% in achievements, and the average maximum angular velocity after test for elite athlete group is larger than sub-elite athlete groups. In speed, three-axis maximum value, with significant differences in sub-elite athletes, in particular, the angular velocity of Y axis is most obvious difference. Through the MEMS sensors, does not affect the actions of the athlete, and can render the difference of operations performance-related parameters from different property athlete.*

Keywords: *accelerometers, finswimming, gyroscopes, Micro Electro Mechanical systems, spectrum analysis.*

1. Introduction

Finswimming was recognized in the International Alliance Conference in Brussels with the federal representatives of Germany, Belgium, Brazil, France, Greece, Italy, Morocco, Portugal, Swiss Confederation, the U.S. and Yugoslavia on September 28, 1958, upon the disciplines of all aquaticsports. The Confederation Mondiale des Activites Subaquatiques (CMAS) was founded at the conference in Morocco, held from January 9 to 11, 1959. Finswimming thus becomes one of the sporting events of CMAS, but only with a short history of fifty years.

As a new sport, finswimming is characterized by diving and racing. It combines four movement skills, including diving, turning, stroking and touch. Those movement skills form the complex and highly skillful sports. Finswimming speed is derived from the swimmer's flipper movement. When the swing frequency is high, the amplitude is large, and the advance speed is also high. Good swimmers use higher swing frequency, but the higher swing frequency reduces the amplitude relatively. To obtain excellent performance, the swimmer's ability should be distributed appropriately in the overall racing process, so as to maximize his/her ability to attain optimum performance.

This study aims to use microelectromechanical system (MEMS) sensor to analyze the swing frequency and amplitude of finswimmers, as well as the effect of various kinematic parameters on the performance of finswimmers. The results can provide reference for coaches and swimmers on future training. This study used MEMS sensors, and mounted the accelerometer and gyroscope on the limb segments to measure the acceleration and angular velocity values. The average and standard deviation were calculated. The curvilinear figure of stroking movement of elite swimmers and sub-elite swimmers is drawn for analysis, so as to provide reference frame for swimmers and coaches to improve the performance in fin swimming training.

2. Literature Review

2.1 Huang & Lin (2012) suggested the following operational definitions:

(1) Fast Fourier Transform (FFT): Wu & Chen (2011) indicate that a signal processing algorithm, converting signal from time domain value into frequency domain value. It can determine the main components of a signal. The vertical coordinate of spectrogram is the amplitude or energy of various frequency components; the horizontal coordinate is the frequency. This study used FFT of MatLab to convert the data of time domain into frequency domain data, and used Excel to draw the data into a spectrogram. The cyclic frequency concentration when the flipper swings up and down was determined for the swimmers' data analysis.

(2) Root Mean Square Error (RMSE): the difference between two swimmers in the overall movement time series data was calculated by RMSE. A smaller RMSE value represents smaller difference between their movement time series data and more similar movements. The equation is prediction value:

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[f(i) - f'(i)]^2} \qquad (1)$$

(3) Mean Absolute Percentage Error (MAPE): the difference between two swimmers in the overall

movement time series data was calculated by MAPE. A smaller absolute percentage error value indicates that their data are closer to each other, and the movements are more similar to each other. The equation is:

$$MAPE = \frac{1}{N}\sum_{i=1}^{N}\left|\frac{f'(i) - f(i)}{f(i)}\right| \times 100\% \qquad (2)$$

(4) Analysis of Variance (ANOVA): the ANOVA was used to check whether the mean values of multiple (>2) populations are equal, different from z and t tests for the mean difference between two groups of data. This experiment used One-way ANOVA and significance level of α=0.05 to check whether there is significant difference in the average data of each cyclic movement of all swimmers. The LSD analysis was performed to determine whether there is significant difference.

(5) Fittest: In order to accelerate experimental analysis, the t-test (whether there is significant difference between two groups of mean data) was performed after the F-test (judging similarities and differences between two groups of mean data variance) in this experiment. It was written in the macro of MS Excel to generate commands, thus performing F-test and t-test simultaneously.

2.2 The take-off angle and perspective on the water

Dai (2007) pointed out that the only finswimming discussion papers, finswimming diving athletes in two ways. The difference arch standing and standing of the entire sole; arch standing with feet wide stance departure angle of attack; jump speed; vertical take-off speed; jump horizontal velocity. But over the whole foot arch standing standing to get a better starting speed, and then there are the far distance flight. Athletes diving finger touches instantly the water angle body weight and surface of the horizontal axis is called into the water angle, pitch water angle is too small will cause the body and the surface contact area is too large to increase the resistance. If the water angle is too large it will result into the water too deep to affect gliding distance.

Pearson et al. (1998) pointed to the age of 14 ± 3.57 years of 18 swimmers for the subjects. The difference of analyzed and compared between the grip grabbing start and the starting formula, found grabbing start of into the water angle of 43 ± 11.9 degrees, into the water at the regional level was 0.88 ± 0.3 meters; grip style into the water angle of departure of 43 ± 10.1 degrees, into the water at the regional level was 0.79 ± 0.4 meters. But the two departure ways angle into the water and a range into the water are not significant differences.

Groves & Roberts (1970) pointed out that the 16 male players of University to do the kinematic analysis and to explore the best take-off swim angle. They use gravity moving angle for the player starts as a take-off angle. It was found that obtained the formula which is the best take-off angle and the horizontal angle of 13 degrees downward, to have the maximum level of the starting speed. And 16 subjects who participated in the experiment, there are the take-off angle from 20 degrees down to 14.92

degree, so players should be able to do further strengthened in this regard.

2.3 The swing, frequency, strength, coordination of Finswimming2

Huang and Lin (2012) pointed out that the Finswimming motion carry out a wide range of a sport around the world. The European countries more flourished than Asian countries, but Chinese mainland tried to promote in recent decades. Also accounted for a place in the World Championship bit. Finswimming enhance athletic performance to depend on the hydrodynamic performance of physical fitness, sports technology and sports equipment, the key is to improve sports technology and sports equipment of enhance hydrodynamic performance. while improving finswimming techniques and training methods, to strengthen research of finswimming board material and hydrodynamic performance. The improvements in forward finswimming performance of board material is urgently a problem of finswimming motion to need to improve.

Zhen, Han, O, & Shu (1997) pointed out that studies in different webbed frequency, amplitude changes under conditions webbed thrust, lateral forces and moments proposed short, medium and long finswimming technique webbed frequency, amplitude webbed how With the rationalization proposals. And he noted that when the human body as a whip to drive flippers motion, lower limb joints especially the positive rotation of the ankle joint play an important role in improving the thrust.

O (2001) pointed out that competition-based sports training practice from the perspective of analyzing the mechanics of small amplitude surface finswimming, water whip high frequency technology is reasonable, webbed different frequency, amplitude under conditions webbed thrust, lateral forces and moments the change. He proposed that short, medium and long webbed frequency of finswimming technique how to match the web webbed rationalization proposals, and noted that the human body in motion driven flippers.

3. Research Method

3.1 Study object:

The three best players of each study, height 166.0 ± 2.6 cm, weight 64.0 ± 2.6 kg, aged 17 ± 1.7 years. Times good players height 160.3 ± 1.5 cm, weight 58.7 ± 3.1 kg, aged 13.7 ± 1.2 years, the players best result as "Table 1" and "Table 2" below.

Table 1 Elite players basic information on best score

Elite players	（code）	personal best performance
○-Lun Guo	A	A World Cup training athletes, the National Fin Swimming Championships 50,100 meters high first female group
○-Yin Jin	B	Championships 1500 meters athletes, the third NationalGames 200m International fin swimming
○-Yu Lin	C	100,200 meters adolescents first Tournament

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Table 2 Sub-elite players basic information on best score

Sub-elite players	（code）	personal best performance
○-Yi Hung	D	tional Fin Swimming Championships 50-meter high female group of urface fin swimming
○-Yi Liao	E	National Women 100m surface fin swimming group National Instrument fourth Fin Swimming Championships
○-Wei Hung	F	Country female group 100-meter water surface fin swimming Fin Swimming National Championships fifth

3.2 System Architecture Description

(1)Sending end: the sending end sends the data through low-pass filter (accelerometer 1.507kHz, gyroscope 2.122kHz) sampled at frequency of 1000Hz from accelerometer and gyroscope sensors to the computer. As various limb segments are under different stresses, the sensors with different acceleration measurement range values are selected. The acceleration and gyroscope sensor devices and the direction of motion are introduced in Figures 1~3. The acceleration sensor is worn on the waist (Figure 4), thigh (Figure 5) and leg (Figure 6). The high acceleration measurement range is at the flipper (Figure 7).

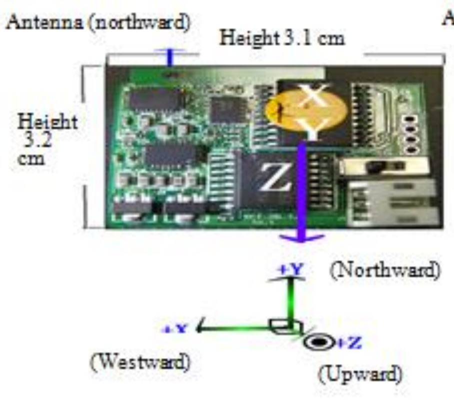

Figure 1 Three-axis direction of high acceleration

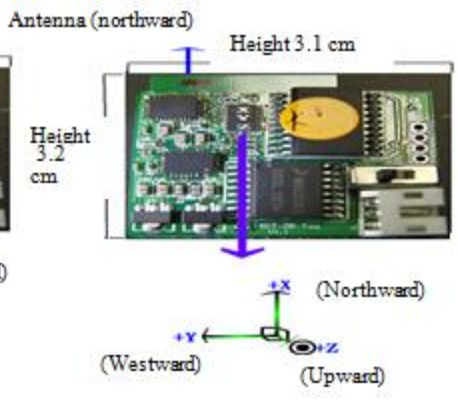

Figure 2 Three-axis direction of low acceleration

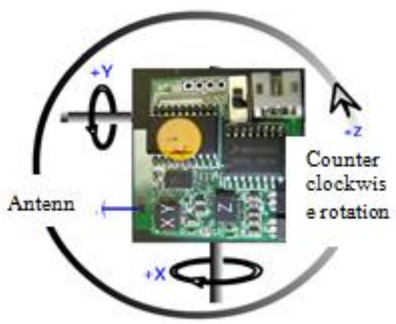

Figure 3 Three-axis direction of angular

The MEMS sensors were mounted in four positions, as shown in Figures 4~7. The limb segments, the acceleration measurement range, the angular velocity measurement range, and the reference figures are shown in Table 3.

Table 3 Measurement range of limb segments

Limb position	**Acceleration measurement range (m/s^2)**	**Angular velocity measurement range(deg/s)**	**Reference figure**
Waist	XYZ ±107.8	±2000	Figure 4
Thigh	XYZ ±107.8	±2000	Figure 5
Leg	XYZ ±107.8	±2000	Figure 6
Flipper	XZ±980 Y±490	±2000	Figure 7

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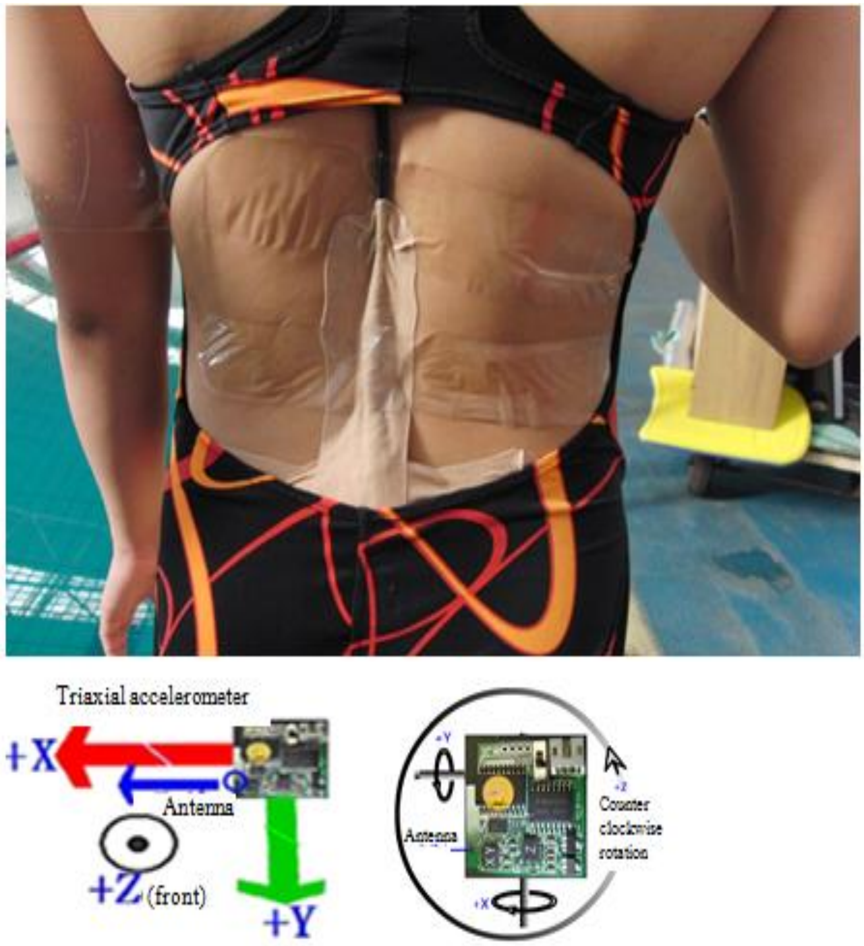

Figure 4 Sensor on waist

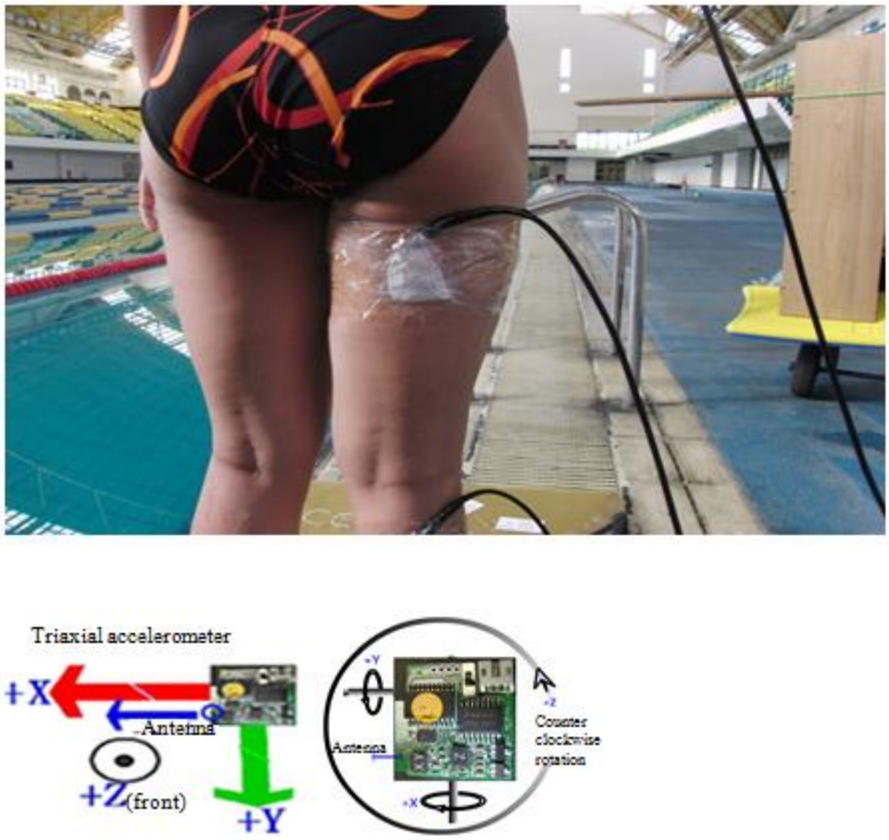

Figure 5 Sensor on thigh

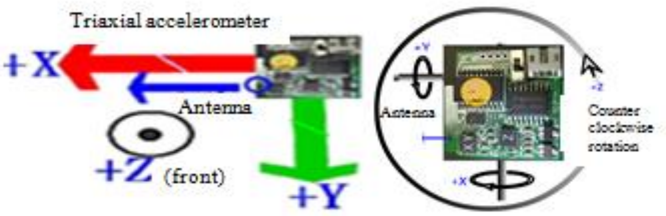

Figure 7 Sensor on flipper

(2)Value receiving stage: the sending end transmits data by wire transmission to the receiving end. The receiving end transfers the data via 8-port high speed RS-232 adapter card to the computer, and the correction file and setting file form data file.

(3)Analysis stage: the data of two rounds of 50 m successful surface finswimming are collected by wire transmission in the experiment. About 39700 data from the beginning to the end are saved in files. The data are processed by MATLAB software as analysis data, and compiled by MS Excel as basis of comparison. The professional experience is combined with scatter diagram and VBA program analysis to convert the trips of each swimmer into 29~46 cycles for analysis, so as to judge the differences between swimmers.

(4)Data formation process: when the sending end, receiving end and saved file numbers of MEMS sensors are set. The computer starts up the wired MEMS sensors on the swimmers via software interface, and gives light signal and warning sound to remind the researcher that the experiment has begun. The high-speed camera is switched on and the swimmer prepares for the 50 m surface finswimming. The MEMS sensors collected the swimmers' movement data. The sending end transmits data by wire transmission to the receiving end. The receiving end transfers data to the computer, saved as *.csv data file. The data file is compiled, tested and analyzed by MS Excel 2007and MatLab software, and validated by experts.

(5)System framework (Figure 8): each sensor on the swimmer corresponds to a preset numbered receiver. The data are sent to the computer by wire transmission, and the set file name is imported and saved as file.

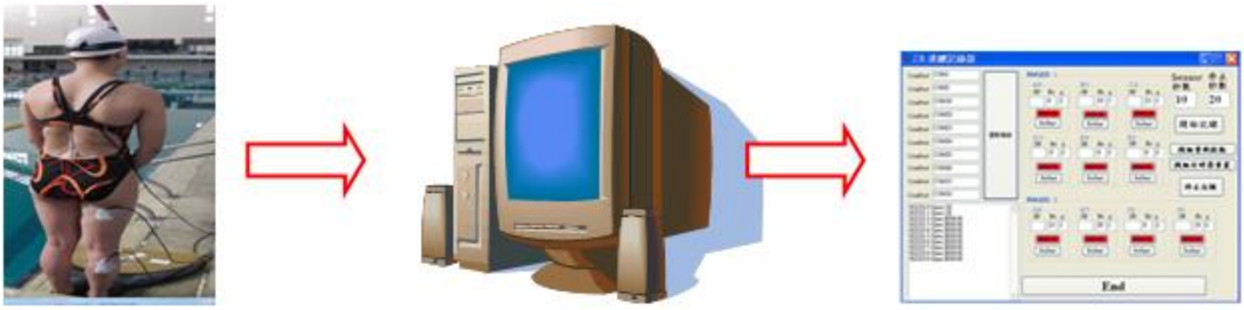

Figure 8 System framework

4. Data Analysis and Results

According to the scatter diagram of main frequency distribution area 6Hz data of movement, there are two main amplitudes. The spectrum data are divided into low frequency (1~2Hz) and high frequency (2.5~3.5Hz), as shown in Figure 9. The statistical analysis is repeated for further comparison.

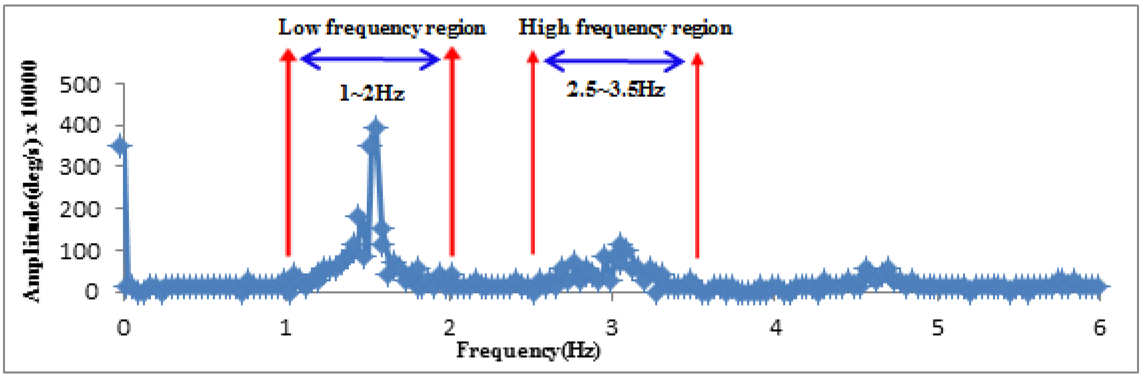

Figure 9 Frequency separation of spectrum data

This study used MEMS sensors to analyze the movements of elite swimmers and sub-elite swimmers during 50 m surface finswimming. The three-axis acceleration and angular velocity values of flipper and four limb segments were calculated and analyzed by MatLab and Excel. The analysis results are as follows:

4.1 The swing frequency was calculated by FFT, and the results were very close to that calculated by curve. The percentage error of swing frequency was about 3%, proving that the FFT could calculate swing frequency quickly and accurately (Tables 4~5).

Table 4 Swing frequency of elite swimmers calculated by manual operation, curve and FFT

Elite swimmers	Swing frequency calculated by manual operation (times/second)	Swing frequency calculated by curve (times/second)	FFT swing frequency (times/second)	Swing frequency error between FFT and curve (%)
A1	1.47	1.52	1.56	2.63%
A2	1.38	1.43	1.43	0.00%
B1	1.64	1.58	1.62	2.53%
B2	1.51	1.58	1.53	-3.16%
C1	1.54	1.56	1.64	5.13%
C2	1.45	1.48	1.46	-1.35%

Table 5 Swing frequency of sub-elite swimmers calculated by manual operation, curve and FFT

Sub-elite swimmers	Swing frequency calculated by manual operation (times/second)	Swing frequency calculated by curve (times/second)	FFT swing frequency (times/second)	Swing frequency error between FFT and curve (%)
D1	1.44	1.46	1.46	0.00%
D2	1.66	1.74	1.74	0.00%
E1	1.03	1.07	1.07	0.00%
E2	0.91	0.97	0.98	1.03%
F1	1.40	1.41	1.40	-0.71%
F2	1.39	1.38	1.37	-0.72%

4.2 MAPE test analysis result of flipper angular velocity swing spectrum data of swimmers

(1)Low frequency data analysis: according to the full frequency data, the highest frequency amplitude occurred at 1~2Hz, so the swing spectrum data within 1~2Hz were extracted as low frequency data. The MAPE value cluster statistics of low frequency data are shown in Tables 6~8. The elite swimmer group has similar swing frequency response, and the swing frequency response of the elite swimmer group is obviously different from that of the sub-elite group. There is no significant difference between the elite swimmer group and the sub-elite swimmer group in the swing frequency response.

Table 6 Low frequency XYZ axes MAPE Value cluster statistics

XYZ axes	Cluster statistics	
	Elite	Sub-elite
Elite	12/30	
Sub-elite	5/42	24/42

Table 7 Low frequency YZ axes MAPE Value cluster statistics

YZ axes	Cluster statistics	
	Elite	Sub-elite
Elite	17/30	
Sub-elite	7/42	24/42

Table 8 Low frequency Y axis MAPE Value cluster statistics

Y axis	Cluster statistics	
	Elite	Sub-elite
Elite	26/30	
Sub-elite	21/42	21/42

(2)High frequency data analysis: according to the full frequency data, there is another high amplitude when the frequency amplitude is 2.5~3.5Hz, so the swing spectrum data during 2.5~3.5Hz are extracted for high frequency data analysis. The MAPE value cluster statistics of high frequency data are shown in Tables 9~11. There is no significant difference between the elite swimmer group and the sub-elite swimmer group in the swing frequency response.

Table 9 Low frequency XYZ axes MAPE Value cluster statistics

XYZ axes	Cluster statistics	
	Elite	Sub-elite
Elite	18/30	
Sub-elite	2/42	25/42

Table 10 Low frequency YZ axes MAPE Value cluster statistics

YZ axes	Cluster statistics	
	Elite	Sub-elite
Elite	19/30	
Sub-elite	4/42	27/42

Table 11 Low frequency Y axis MAPE Value cluster statistics

Y axis	Cluster statistics	
	Elite	Sub-elite
Elite	30/30	
Sub-elite	33/42	34/42

4.3 ANOVA of maximum value and minimum value of flipper angular velocity and acceleration time domain data of swimmers and total power and triaxial total power

(1) ANOVA of maximum angular velocity mean of flipper time domain data

ANOVA: according to Table 12, the maximum angular velocity mean is on Y-axis, i.e. when the flipper swings downward. The Y-axis maximum angular velocity mean of the elite swimmer group (A1~C2) is 659 (deg/s), the Y-axis maximum angular velocity mean of the sub-elite swimmer group (D1~F2) is 436 (deg/s).

Table 12 Time domain data flipper triaxial maximum angular velocity mean statistics

Swimmer	X axis			Y axis			Z axis		
A1	199	±	46	857	±	68	78	±	11
A2	236	±	71	752	±	46	72	±	17
B1	250	±	66	648	±	62	88	±	19
B2	238	±	65	633	±	80	85	±	19
C1	157	±	49	528	±	32	56	±	15
C2	158	±	46	539	±	32	74	±	18
D1	100	±	27	507	±	101	60	±	19
D2	116	±	23	532	±	68	55	±	12
E1	59	±	23	394	±	29	34	±	16
E2	77	±	38	403	±	20	32	±	13
F1	95	±	25	426	±	76	36	±	6
F2	94	±	28	356	±	63	45	±	5

Note：(unit deg/s)

(2) ANOVA of flipper time domain data minimum angular velocity mean:

ANOVA: according to Table 13, the minimum angular velocity mean is on Y-axis, i.e. when the flipper swings upward. The Y-axis minimum angular velocity mean of the elite swimmer group (A1~C2) is -596(deg/s), the Y-axis minimum angular velocity mean of the sub-elite swimmer group (D1~F2) is -361 (deg/s).

Table 13 Time domain data flipper triaxial minimum angular velocity mean statistics

Swimmer	X axis			Y axis			Z axis		
A1	-156	±	47	-534	±	105	-68	±	17
A2	-188	±	29	-678	±	148	-83	±	22
B1	-236	±	54	-634	±	88	-79	±	15
B2	-238	±	53	-577	±	112	-82	±	17
C1	-203	±	37	-578	±	62	-64	±	9.9
C2	-196	±	35	-577	±	103	-50	±	11
D1	-115	±	24	-538	±	37	-53	±	17
D2	-86	±	23	-522	±	43	-50	±	17
E1	-91	±	25	-249	±	86	-51	±	12
E2	-94	±	28	-185	±	15	-48	±	19
F1	-69	±	25	-382	±	38	-36	±	14
F2	-88	±	22	-292	±	58	-33	±	10

Note：(unit deg/s)

(3) ANOVA of angular velocity total power of flipper time domain data X, Y and Z axes:

ANOVA: the angular velocity total power of X, Y and Z axes is calculated respectively (square sum of angular velocity). After the One-way ANOVA on angular velocity total power in various cycles (significance level set as $\alpha=0.05$), the X, Y and Z axes have significant difference, meaning that the swimmers have different triaxial angular velocity total power values. Table 14 shows that the maximum value of triaxial angular velocity total power mean is on Y-axis.

Table 14 Time domain data triaxial angular velocity total power statistics

Swimmer	X axis			Y axis			Z axis		
A 1	2222602	±	543663	104214355	±	8213886	704793	±	309666
A 2	3093712	±	667444	97307805	±	16517478	668308	±	335327
B 1	7075840	±	1930437	86582952	±	11678847	827582	±	323187
B 2	6417352	±	2593747	73073965	±	15998600	723299	±	287888
C 1	3755936	±	1166032	57192571	±	6903232	420654	±	146245

C 2	3252081	±	872941	60277959	±	7473674	446365	±	159995
D 1	1383178	±	504170	46616200	±	8003409	453208	±	287452
D 2	730888	±	317582	42759426	±	5164445	329770	±	116247
E 1	545476	±	429344	27697214	±	5483132	273684	±	171395
E 2	656582	±	252327	32155227	±	2540908	159650	±	60980
F 1	642286	±	227348	34898198	±	3836888	172877	±	75584
F 2	453635	±	138990	29175360	±	4054759	185652	±	47714

Note:（unit: deg/s）^{2})

5. Conclusion and Suggestions

5.1 Conclusion

(1) FFT for calculating swing frequency: the swing frequency is difficult to be calculated manually, only the average swing frequency is obtained. The curve conversion is accurate, but it is time consuming. Therefore, this study used FFT to calculate the swing frequency. The percentage error of swing frequency is about 3%, proving that the FFT could calculate swing frequency quickly and accurately.

(2) MAPE test analysis result of swing spectrum data:

i. Low frequency data analysis: the MAPE values of low frequency (1~2Hz) data of swimmers are calculated in clusters. Considering the XYZ axes, the absolute percentage error between elite swimmers is small, and the MAPE between the elite swimmer group and the sub-elite swimmer group is very large. The MAPE value of the elite swimmer group is lower than the mean of 86.7%, and the MAPE value of the sub-elite swimmer group is lower than the mean of 50%.

ii. High frequency data analysis: the MAPE values of high frequency (2.5~3.5Hz) data of swimmers are calculated in clusters. Considering XYZ axes, the MAPE between elite swimmers is small, and the movements are similar. The MAPE between the elite swimmer group and the sub-elite swimmer group is very large, and the movements are different. The same result is found in YZ axes. The Y-axis data are especially obvious. The MAPE value of the elite swimmer group is lower than the mean of 100%, and the MAPE value of the sub-elite swimmer group is lower than the mean of 80.9%. Therefore, the elite swimmers have similar swing frequency response, and their swing frequency responses are significantly different from that of sub-elite swimmers. There is no significant difference between sub-elite swimmers and sub-elite swimmers in the swing frequency response.

(3) ANOVA of maximum angular velocity mean of flipper time domain data of swimmers

ANOVA: the 12 times of 50 m surface finswimming movements of 6 swimmers are analyzed into cyclic data. The maximum value (i.e. maximum angular velocity of flipper swing down) is used for One-way ANOVA in various cycles (significance level set as α=0.05). X, Y and Z axes have significant difference, meaning that there is difference between swimmers in the triaxial forward maximum angular velocity mean (flipper swing down). The ANOVA on three axes of the elite swimmer group shows that there is significant difference between elite swimmers in triaxial forward maximum angular velocity mean. The ANOVA test of three axes of the sub-elite swimmer group shows that there is significant difference between sub-elite swimmers in triaxial forward maximum angular velocity mean.

(4) ANOVA of minimum angular velocity mean of flipper time domain data of swimmers

ANOVA: the 12 times of 50 m surface finswimming movements of 6 swimmers are analyzed into cyclic data. The minimum angular velocity mean of flipper (i.e. maximum angular velocity mean of flipper upswing) is used for One-way ANOVA in various cycles (significance level set as α=0.05). X, Y and Z axes have significant difference, meaning that there is a significant difference between swimmers in minimum angular velocity mean (maximum angular velocity mean of flipper upswing). The ANOVA of three axes of the elite swimmer group shows that there is a significant difference between elite swimmers in triaxial minimum angular velocity mean. The ANOVA test of three axes of the sub-elite swimmer group shows that there is a significant difference between sub-elite swimmers in triaxial minimum angular velocity mean.

(5) ANOVA of flipper time domain data total power and triaxial total power of swimmers

ANOVA: the angular velocity total power of X, Y and Z axes is calculated respectively, after ANOVA (one-way ANOVA) test of angular velocity total power in various cycles (significance level set as $\alpha=0.05$), the X, Y and Z axes have significant differences, meaning that there is difference between swimmers in triaxial angular velocity total power value. The ANOVA of three axes of the elite swimmer group shows that there is a difference between elite swimmers in triaxial angular velocity total power. The ANOVA of three axes of the sub-elite swimmer group shows that there is a difference between sub-elite swimmers in triaxial angular velocity total power.

5.2 Suggestions

(1) Finswimming is an unpopular sport, and the field and apparatuses are limited. In fact, coaches and swimmers spend little time on finswimming training. Thus, scientific methods, such as MEMS sensors, are used in finswimming training to improve the performance.

(2) The sub-elite swimmers can enhance the stability and strength in Y direction of flipper according to the measured data, so as to use the training time effectively, and to avoid inappropriate or excessive training causing sports injury.

(3) If the swimmers and coaches could use MEMS sensors to check training results periodically, perform computer analysis, record swimmers' performances quarterly, review the application of force of limb segments, and propose improvement method, the swimming performance can be enhanced, and finswimming can be promoted.

References

Dai, W. H. (2009). Elite athletes start fin swimming action of kinematic analysis. *Master's thesis*, Pingtung University of Education, Pingtung City.

Zhen, G. T., Han, J. R., O, K. P., & Shu, P. (1997). On webbed frequency, amplitude and thrust relationship webbed vertical and lateral torque. *Beijing Sport University.*

Groves, R., & Roberts, J. A. (1970). A further investigation of the optimum angle of projection for the racing start in swimming. *The Research Quarterly, 43*(2), 167-174.

Wu, H. C. & Chen, C. H. (2011). Aa wireless transmission systems used in motion sensing front crawl overland paddlers of information and analysis, *2011 Ares Management and Application Technology Seminar.*

O, K. P. (2001). Mechanics slightly high frequency Technology. *Wuhan Institute of Physical Education.*

Pearson, C. T., Mecelory, G. K., Blitvich, J. D., Subic, A., & Blanksby, B. (1998). A comparison of the swimming start using traditional and modified starting blocks. *Journal of Human Movement Studies, 34*(2), 49-66.

Huang, S. C., & Lin, C. Y. (2012). MEMS Sensors Applied in Finswimming Movement Analysis. *Master's thesis,* Shu-Te University, Kaohsiung, June 2012.