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Biomechanical Analysis to Improve the Grab Starting Performance for the Freestyle 50-Meter Women Swimmers

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Abstract: The purpose of this study was to improve the starting time (grab start) of the freestyle 50-meter women swimmers and to reach predictive mathematical equations representing a scientific basis to improve the starting time. 3 women swimmers from the Port Said University team, selected by the deliberate way, as each swimmer performed three 50-meter swimming trials from above the starting block before performing the specific trainings to improve the performance of the Grab Starting. The results suggested that to obtain a faster start, swimmers should (a) perform the grab start quickly and strongly to help finishing the race distance in less time due to the optimum use of the strong resistance of the starting block in giving the body the maximum speed and efficiency to attain the maximum push power forward, (b) perform the specific exercise for the muscles of legs as it is principally responsible for the positive motor result for the swimmers during start, (c) improving the grab start as it is possible to decrease the race time by 0.10 seconds, (d) keeping the body of the swimmer closer to a straight line as much as possible in order to lessen the fractures that hindrance the smooth movement to achieve the highest possible benefit that helps the swimmer to achieve the farthest distance from the starting block and (e) the swimmer should enter the water with a slope, which gives a bigger chance in the slipping into the water, hence achieving the best distance inside the water and achieving the best time.

Key words: Biomechanical · Grab start · Specific exercise · Swimming

INTRODUCTION

In competitive swimming the goal is to cover a set distance in the least time. This means that a swimmer must start, swim and turn fast. Although the time spent starting is very small, the differences between winning and losing a race are often so small that this time can be decisive.A few investigations have been conducted on this subject. In most cases the results suggest that the grab start is more effective than other starting techniques [1-5]. Although there has been some dispute over which starting technique in swimming is most effective, the grab start has been the most widely used method of starting at all levels of competition for some years. Reported that all six finalists in the 50-yd freestyle at the 1971 National Collegiate Athletic Association (NCAA) Swimming [4].

The United States championships for eligible university swimmers used the grab start. Similar observation with respect to all competitors in the 50-yd freestyle at the 1976 NCAA Swimming and Diving Championships were made [6]. The grab start is common techniques in swimming races [7]. This study aims to identify the effect and determine the contribution ratios among some specific exercises on some biomechanical indicators to improve the starting time (grab start) of the freestyle 50-meter women swimmers and reaching predictive mathematical equations representing a scientific basis to improve the starting time of the freestyle 50-meter women swimmers.

MATERIALS AND METHODS

The researcher utilized the experimental approach, the pre and post design for one group, depending on the mechanical analysis by the fast video analysis method with 3 women swimmers from Port Said University team, selected by deliberate way. Each swimmer performed three 50-meters swimming trials from above starting block before performing the specific trainings to improve the performance of the grab starting. Consequently,

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the number of trials subject to analysis became 9 trials before the application of the specific trainings and 9 trials after applying the specific trainings, so that the total number of trials statistically analyzed became 18 trials. Their age, height, weight, body mass index were 20.139 ± 0.13 years, 1.716 ± 0.015 meter, 60±2.6 kg, 20.372±1.22 kg/m2, respectively (Mean±SD).

The researcher performed the pre-measures on Saturday 13/2/2010 at 3pm, in swimming pool at Port Said stadium. She started by applying the specific exercises for a period of 8 weeks at the rate of 3 sessions per week for 30 minutes per session. Thus, the specific exercises totalled 12 hours after eight weeks and until Wednesday 14/4/2010 on which day the researchers performed the post measures.

Tools and Equipment of Collecting Data: Tools and equipment of Simi analysis, A 21-inch color monitor, One video camera of 60, cadre/second speed, Fastec Imaging brand, one tri stand equipped with a water scales, A 0.50 meter x 0.50 meter square drawing scale.

Statistical Methods: The researcher processes the data using the statistical methods of T test and Multi regression.

The Specific Trainings:

- Forward lunging, placing palms on the floor - pressing the trunk down and staying still for 10 seconds.
- Standing – holding the foot by the opposite hand from behind and staying still for 10 seconds.
- Jumping forward, the two feet together and staying still for 2 seconds.
- Jumping forward, the two feet together, over 20 medical balls placed 25 cm apart from each other.
- Jumping up, the two feet together, over a box 20 cm high, jumping down, jumping over a box 40 cm high, descending, then jumping to cross a barrier 20 cm high.
- Squatting - arms forward, jumping forward, then conglobating the body.
- Placing a cube, 10 cm high in front of the starting block and 20 cm far from the front edge of the starting block. Each swimmer jumps, two feet together, 5 times over the barrier into the water.
- Performing the starting jump completely, concentration is on swinging arms and jumping to the farthest distance.
- Placing guiding signs inside the swimming pool for distant distances and attempting to reach them.

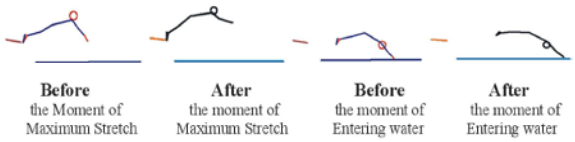

Fig. 1: Stick figure grab start

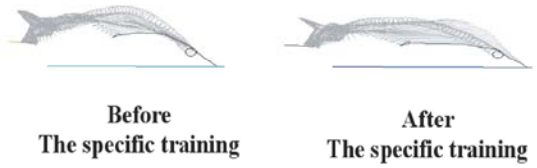

Fig. 2: Curves of grab start

Figures 1 and 2 show the stick figure grab start and curves of grab start.

Table 1 show significant statistical differences between the mean horizontal and vertical displacements in favour of the post measuring to the pre measuring for the selected anatomical points and the time of freestyle 50-meter swimming, except the vertical displacement of the right foot ankle, the moment of maximum stretch on the starting block. The researcher attributes this to the effect of the used specific trainings on the increase of the maximum moving range of the body joints of the female swimmers, which led this stretch case, in the horizontal and vertical direction, to bring nearer the gravity center of the body from the starting block, i.e. below the middle of the back, which led to minimizing the effect of gravitation on the body of the swimmers and consequently her not falling early into the water and attaining the farthest horizontal distance when entering water. The researcher also attributes the statistical non significance for the vertical displacement of the right foot ankle such that the position of the foot ankle during the maximum stretch on the starting bock does not differ between the two measures, because the size of the foot is fixed and did not change. The researcher further attributes the existence of significant statistical differences between the pre measure and post measure for the time of the freestyle 50-meter such that the specific trainings directly affected in improving the swimmer's time in spite of not changing the special training programs of the swimming technique during the pre measuring and post measuring, as the time of freestyle 50-meter swimming before the specific trainings was 47.111 seconds, while it became 43.444 seconds after the trainings, with an improvement ratio of 5.097%. So grab start performance quickly and strongly helps finish the race distance in less time, due to the optimum use of the strong resistance of the starting block in giving the body the maximum speed and efficiency to attain the maximum push power forward.

Table 1: Difference significance and rate of improvement between vertical and horizontal displacements at the moment of maximum stretch for the freestyle 50-meter women swimmers

	After		before			
Anatomical Points	----------		----------			
Rate of improvement	Mean	Variance	Mean	Variance	t Stat	%
Middle finger right x	2.546773	0.017099	2.137424	0.178904	?2.79132	19.15152
Middle finger right y	0.039836	0.078796	-0.01738	0.236768	?2.33721	2391.54
right hip x	1.50232	0.003764	1.35676	0.00068	?5.6628	10.7284
right hip y	0.565788	0.002439	0.70293	0.00301	?6.2392	19.511
right knee x	1.16641	0.00239	1.04277	0.00894	?4.30303	11.857
right knee y	0.36226	0.00159	0.29125	0.00434	?2.3508	24.379
right ankle bone x	0.80706	0.002322	0.59351	0.00925	?6.28139	35.981
right ankle bone y	0.16682	0.005808	0.16244	0.000104	0.16854	2.6977
Right toe x	0.70822	0.00075	0.50307	0.00063	?16.6017	40.7801
Right toe y	0.02091	0.00362	-0.3685	0.000212	?2.9509	156.74
Heel right x	0.75606	0.0011	0.52344	0.0115	?6.68101	44.439
Heel right y	0.218707	0.00126	0.16968	0.001552	?2.98338	28.8932
Timing 50 m swimming	43.444	0.27778	47.1111	1.6111	?8.9814	5.097

* Significantly different at p<.05 =2.306

Table 2: Difference significance and rate of improvement between vertical and horizontal velocities at the moment of maximum stretch

	After		before			
Anatomical Points	----------		----------			
Rate of improvement	Mean	Variance	Mean	Variance	t Stat	%
Middle finger right v x	6.11114	1.416198	5.550671	3.176313	1.024124	10.0968
Middle finger right v y	1.95511	8.439823	-0.69559	2.786471	?3.1877	381.074
Right hip v x	4.31344	0.036083	4.42946	0.800101	0.39198	2.6191
Right hip v y	-1.04319	0.146735	-1.42997	0.480827	1.61788	27.047
Right knee v x	2.56347	0.0090577	2.52826	0.57448	0.134085	1.3925
Right ankle bone y	0.16682	0.005808	0.16244	0.000104	0.16854	2.6977
Right ankle bone v x	2.57944	0.345002	2.72943	0.54235	0.5441	5.4954
Right ankle bone v y	1.75432	0.04672	1.165311	0.11624	?3.7383	50.545
Right toe v x	1.25948	0.39021	1.14067	0.11753	0.48323	10.415
Right toe v y	1.96477	0.23516	1.61539	0.25164	1.64823	21.628
Heel right v x	3.23928	0.18882	3.08854	0.96968	0.44918	4.8805
Heel right v y	2.01917	0.11167	1.3663	0.15019	?3.5113	47.782

* Significantly different at p<.05 =2.306

Table 3: Difference significance and rate of improvement between the average vertical and horizontal displacements at the moment of entering water for the freestyle 50-meter women swimmers

	After		before			
Anatomical Points	----------		----------			
Rate of improvement	Mean	Variance	Mean	Variance	t Stat	%
Middle finger right x	3.70099	0.05441	3.28408	0.09593	?4.0814	12.16152
Middle finger right y	-0.6865	0.00015	-0.7511	0.00281	?3.3965	8.5928
Right hip x	2.87615	0.0919	2.49535	0.10166	?3.1519	15.261
Right hip y	0.0117	0.00402	-0.017	0.01297	0.6137	168.989
Right knee x	2.4575	0.10650	2.0446	0.10529	?2.9380	20.193
Right knee y	0.03339	0.031	0.11496	0.01077	1.2944	70.4319
Right ankle bone x	2.0856	0.0969	1.65751	0.11709	?2.9116	25.827
Right ankle bone y	0.13422	0.16387	0.29753	0.010344	1.3051	54.888
Right toe x	1.94326	0.1163	1.43428	0.13519	?3.3598	35.486
Right toe y	0.01195	0.25315	0.28736	0.0129	1.0474	58.38
Heel right x	2.0746	0.06804	1.66262	0.11054	?3.1753	24.782
Heel right y	0.19311	0.17652	0.36491	0.01139	1.2912	47.078

* Significantly different at p<.05 =2.306

Table 2 shows significant statistical differences between the average vertical velocities of the middle toe, the right foot ankle and the right heel in favour of the pre measuring. The researcher explains this such that the specific trainings affected the improvement of the start speed, as the speed of the right toe increased from 2.786471 to 8.439823, with an improvement percentage of 381.074%. This speed led to directing the swimmer's body forward and up. We also notice from the same table that there are significant statistical differences for the vertical velocities of the right foot ankle as the speed increased in the pre measuring from 1.165311 meter/s to 1.75432 meter/s and the right foot heel as the peed increased in the pre measuring from 1.3663 meter/s to 2.01917 meter/s, with an improvement ratio of 47.782%.

The researcher attributes this such that the specific trainings affected the muscular strength of the legs and that the force featured by the velocity the body attained from the moment of stretching the body from the pushing process of the starting block is a result of the process of the maximum bending of the body of the swimmer on the starting block, as well as the process of starting and ending the stretching on the starting block. Therefore, the speed of the toe, the foot ankle and the foot heel is the outcome of this previous process. So the researcher concluded that the muscles of the buttocks and legs are principally responsible for the positive motor result for the swimmers during start.

Table 3 shows that there are significant statistical differences between the average horizontal displacements of the selected anatomical points in favour of the pre measuring. The researcher attributes this such that the specific trainings affected the improvement of the horizontal displacement of the links of the swimmers bodies, as the amount of the horizontal displacement of the swimmers entry into the water for the point of the right hand finger for the post measuring was 3.70099, i.e. an increase of 0.42 meters, which gave the swimmers preference to reach the farthest horizontal distance inside the water.

This leads to improving the start time, hence improving the time of freestyle 50-meter. The researcher attributes this to the effect of the special specific trainings of force featured by peed for the two legs which increased momentum of the strength of pushing the body of the swimmers on the starting block and consequently the improvement of the horizontal displacement of the swimmers body the moment of entering water.

We also notice from the same table that there are significant statistical differences between the average vertical displacements of the right finger the moment of entering water, as the value of the vertical displacement for the post measuring for the hand finger was 0.6865 meter, measured from the beginning of the starting block, while the vertical displacement after the specific trainings was 0.7511 meter.

The researcher attributes this such that the body, in the pre measuring, was perpendicular to the point of entering water, while in the post measuring, this angle was decreased in order to give a bigger chance to make the slipping inside the water and close to the surface of water. This does not happen if the swimmer's hand entered inside the water in a perpendicular position because this will push the body of the swimmers down inside the water, which means the full diving of body of the swimmers inside the water, a position that negatively affects the time of the freestyle 50-meter swimming. This corresponds with Maglischo [8] that with the improvement of the starting skill, it is possible to decrease the race time by 0.10 seconds. Therefore, we have to determine the special biomechanical indicators of the grab start of the freestyle 50-meter swimming, through the motor analysis of the grab. As such, the current study is concerned with identifying the technical properties of the start.

Table (4) shows that there are significant statistical differences between the average vertical speed of the middle finger, the right foot ankle and the right heel in favour of the post measure to the pre measure. The researcher attributes this such that the specific trainings improved the vertical speed of the body joints of the swimmers towards water as an outcome to improving force featured by speed of the legs of the swimmers [9].

Table 5 shows specific of multiple regression analysis of the average vertical and horizontal velocities and displacements the moment of maximum stretch, the vertical displacement indicator for the right knee is the first indicator (Fig. 3), as it contributed with a rate of 99.1256% and the most contributing indicator in improving the starting time in the 50-meter swimming race, as the value of the vertical displacement of the right knee was 0.362267 cm above the starting block, which means the largest stretch of the knee during the moment of maximum stretch, which gives a bigger chance to the women swimmers to fully benefit from the transfer of the impetus of the starting block to the body of the women swimmers. This means entering the water with a slope,

Table 4: Difference significance and rate of improvement between average vertical and horizontal velocities the moment of entering water stretch for the freestyle 50-meter swimmers

Anatomical Points	After		before			
Rate of improvement	Mean	Variance	Mean	Variance	t Stat	%
Middle finger right v x	3.2313	3.1881	3.01988	1.44755	0.32335	7.0011
Middle finger right v y	-3.24414	1.2864	-2.07271	1.404233	?2.4112	56.517
Right hip v x	4.50407	0.0949	4.6233	0.16638	1.1545	2.578
Right hip v y	-2.9636	0.23053	-3.0975	0.2298	0.8636	4.322
Right knee v x	4.4989	0.09443	5.09131	4.22568	0.7458	11.4605
Right knee v y	-2.6024	0.48657	-2.21728	0.66924	1.29956	17.371
Right ankle bone v x	5.19169	0.39393	5.44335	1.2345	0.5096	4.6232
Right ankle bone v y	-2.3072	2.94343	-1.1064	1.90057	?2.77105	108.541
Right toe v x	5.3855	0.872033	5.74229	0.81572	0.7348	6.21308
Right toe v y	-2.18822	2.09877	-0.8946	2.5539	?2.5539	144.603
Heel right v x	5.3855	0.87203	5.74229	0.81572	0.7348	6.213
Heel right v y	-2.1882	2.0987	-0.8946	2.1303	?2.5539	144.602

* Significantly different at p<.05 =2.306

Table 5: Analysis of multiple regressions of the vertical and horizontal velocities and displacements the moment of maximum stretch

Anatomical Points	average	Standard error	residuals	F	p1	p2	P3	P4	% percentage
right knee Y	0.362267	4.308958	0.418784	907.005	118.768				99.12569
right ankle-bone v(Y)	1.75432	4.507007	0.402735	414.678	87.8591	6.39182			99.16304
heel right v(Y)	2.019175	4.319338	0.318077	301.537	132.839	10.1784	-11.32		99.3411
heel right Y	0.218707	4.583615	0.29559	200.908	201.697	-8.0006	-30.04	204.6634	99.38167

not perpendicularly to the water, at the moment of maximum stretch, which gives a bigger chance to the women swimmer to fully benefit from slipping into the water. Thus, we can reach the following predictive regression line equation:

$Y = a + p^1 \times X^1$

Y = Time of swimming 50-meter

A = Constant

X^1= Arithmetic average of the first indicator

P1 = residuals

$Y = 0.418784 + 118.768 \times 0.362267 = 43.444$

Table 5 shows that the second indicator of the vertical speed of the right foot ankle is the second indicator (Fig.4) as to the contribution to improve the starting skill, as it raised the rate of contribution from 99.1256% to 99.16304%. The researcher explains this as the vertical speed of the foot ankle increases at the moment of the maximum stretch on the starting block leads to the greatest benefit from the impetus of the starting block [10]. Thus, the following predictive regression line equation can be attained:

$Y = a + p^1 \times X^1 + p^2 \times X^2$

$Y = 0.402735 + 87.8591 \times 0.362267 + 6.39182 \times 1.75432 = 43.444$

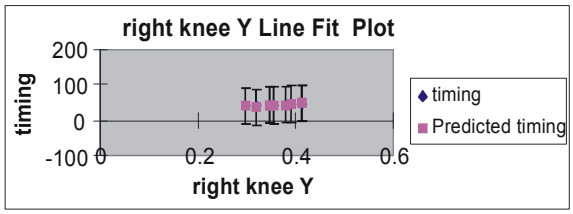

Fig. 3: First Indicator,the vertical displacement indicator for the right knee

Table 5 shows that the third indicator of the vertical speed of the right foot heel (Fig.5) is the third indicator, as to the contribution to the performance of the starting skill, as it raised the rate of contribution from 99.16304% to 99.3411%. The researcher traces this such that by the quick move of joint of the foot ankle in the vertical direction, leads to the transfer of this speed to the foot instep and consequently helps the swimmer for a quick launch. Thus, we can attain the following predictive regression line equation:

$Y = a + p^1 \times X^1 + p^2 \times X^2 + p^3 \times X^3$

$Y = 0.318077 + 132.839 \times 0.362267 + 10.1784 \text{ x } 1.75432 + -11.32 \times 2.019175 = 43.4444$

Table 5 shows that the vertical displacement of the right foot heel (Fig. 6) is the fourth indicator, as to

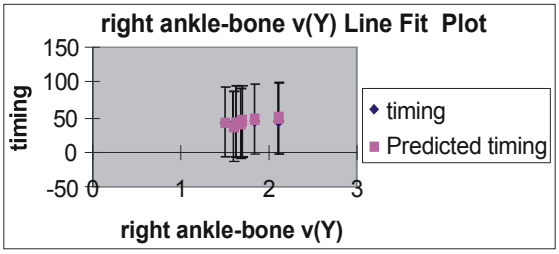

Fig. 4: Second Indicator, the vertical speed of the right foot ankle

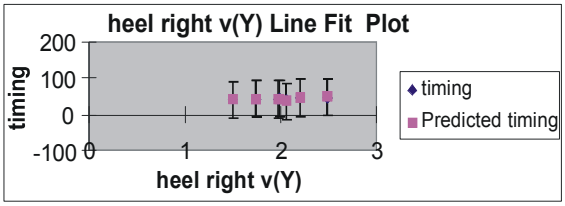

Fig. 5: Third indicator, the vertical speed of the right foot heel

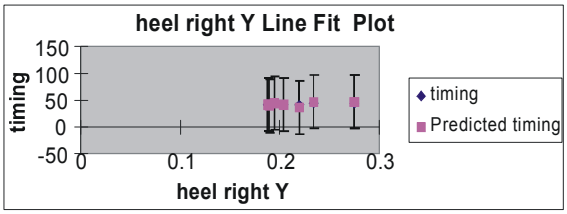

Fig. 6: Fourth indicator, the vertical displacement of the right foot heel

the contribution to the performance of the starting skill, as it raised the rate of contribution from 99.3411% to 99.38167%. The researcher traces this such that in order for the swimmer to benefit from the launching speed from above the starting block, the swimmer has to raise the heel up so that the angles of the body are close, so the body of the swimmer is closer to a straight line, so the fractures that hindrance the smooth movement will be less, so it achieves the highest possible benefit that helps the swimmer to achieve the farthest distance from the starting block [11]. Thus we can obtain the following predictive regression line equation:

$$Y = a + p^1 \text{ x } X^1 + p^2 \text{ x } X^2 + p^3 \text{ x } X^3 + p^4 \text{ x } X^4$$

$$Y = 0.362267 + 201.697 \times 0.218707 + -8.0006 \times 1.75432 + -30.04 \times 2.019175 + 204.6634 \times 0.218707 = 43.4444.$$

Table 6 shows that the indicator of the horizontal speed of the right foot is the first indicator (Fig.7) as it contributed with a percentage of 98.60813%.

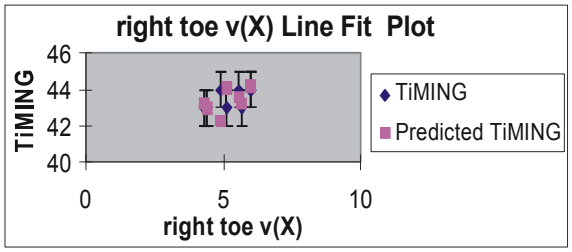

Fig. 7: First indicator, the horizontal speed of the right foot

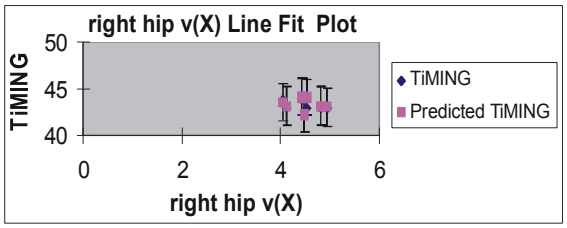

Fig. 8: Second Indicator, the horizontal speed of the right stem

It is the most contributing indicator in improving the starting time for the 50-meter swimming race, as the horizontal speed of the right foot was 5.160371 meter/s at the moment of entering water. The researcher traces this such that the right toe v x indicator represents the speed of the whole body, because the body of the swimmer at this moment is like a spear when it falls to the ground, which means the quick entry into the water. Thus, the following predictive regression line equation is attained:

$$Y = a + p^1 \times X^1$$
$$Y = 0.639073 + 8.29444 \times 5.160371 = 43.444$$

It also appears from Table 6 that the indicator of the horizontal speed of the right stem is the second indicator (Fig.8) to improve the start time, as it raised the rate of contribution from 98.60813% to the rate of 99.92043%. The researcher traces this to the horizontal speed of the body towards water [12]. Thus, the following predictive regression line equation can be attained:

$$Y = a + p^1 \times X^1 + p^2 \times X^2$$
$$Y = 0.032934 + 3.037083 \times 5.160371 + 6.158408 \times 4.504077 = 43.444$$

It also appears from Table 6 that the indicator of the middle finger right y, is the third indicator contributing to the improvement of the start time, as it raised the rate of contribution from 99.92043% to 99.97437%, as the value of the vertical displacement in the post measure was -0.6865

Table 6: Analysis of the multiple regressions of the average displacements, the vertical and horizontal speed at the moment of entering water

Anatomical Points	average	Standard error	residuals	F	p1	p2	P3	% percentage
Right toe v x	5.160371	5.436728	0.639073	566.768	8.29444			98.60813
right hip (vx)	4.504077	1.389636	0.032934	4395.314	3.037083	6.158408		99.92043
Middle finger right y	-0.68656	0.85192	0.006816	7800.771	1.39692	0.638755	-48.578	99.97437

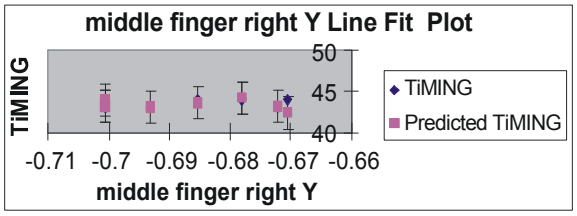

Fig. 9: Third indicator, the middle finger right y

from the starting block, while it was -0.7511 in the pre measure. The researcher traces this such that the swimmer's entering the water with a slope, which gives a bigger chance in the slipping into the water, hence achieving the best distance inside the water and achieving the best time. Thus, the following predictive regression line equation can be obtained:

$$Y = a + p^1 \times X^1 + p^2 \times X^2 + p^3 \times X^3$$

$$Y = 0.006816 + 1.39692 \times 5.160371 + 0.638755 \times 4.504077 + -48.578 \times 0.68656 = 43.444$$

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