Performance Characteristics of Two-Wheeled Push-Type Razor™ Scooters

Timothy J. Reust
Accident Science

Abstract

This paper will outline the results of dynamic tests conducted with two-wheeled push-type Razor™ scooters. The test data was recorded by an electronic data acquisition system via sensors attached to the scooter. The testing involved different age, height and weight male scooter operators. A total of 108 tests were conducted.
The tests included: (a) Coasting downhill on different sloped roadways with constant grades to determine speed and time versus distance. (b) Maximum effort and normal effort acceleration on a level road surface to determine speed and time versus distance. (c) Maximum brake effort on sloped and level road surface to determine tire mark characteristics and deceleration rates.
The results of the testing are provided to aid in the reconstruction of accidents involving this type of scooter.

Résumé

Cette communication présentera un aperçu des résultats des essays dynamiques effectués avec sur des trottinettes à deux roues à butée poussée RazorT. Les données d'essai ont été enregistrées par un système électronique d'acquisition de données par le biais de détecteurs fixés à la trottinette. Les essais ont impliqué des conducteurs de sexe masculin de différents âges, tailles et poids. Les essais incluaient : (a) Roulage en descente sur différentes voies en palier avec des niveaux constants pour déterminer la vitesse et le temps par rapport à la distance. (b) Accélération à l'effort maximal et à l'effort normal sur une route en palier pour déterminer la vitesse et le temps par rapport à la distance. (c) Effort maximal de freinage sur des surfaces en pente et en palier pour déterminer les caractéristiques des marques de pneu et les taux de décélération. Les résultats de ces essais sont fournis pour aider à la reconstruction des accidents mettant en cause ce genre de trottinettes.

Introduction

The Razor™ scooter first entered the market at the end of 1999 and went on to become a must-have item in the year 2000. Industry analysts estimate that up to five million scooters were sold in the year 2000. These scooters are primarily used by children age five to early teens, but also used by adults for recreation and alternative transportation in traffic congested or scarce parking areas.

The Consumer Product Safety Commission estimated that there have been about 40,500 emergency room treated injuries associated with the scooters between January 2000 and December 31, 2000. About 85 percent of the injuries are to children under 15 years of age and two-thirds of the injuries were to males. Most injuries resulted when riders fell from the scooter. The most common injury was a fracture (29%), most often to the arm or hand.

Currently there are no known published studies concerning the performance characteristics of this type scooter and operator. The purpose of this study was to quantify some of these characteristics and provide methods of analyzing scooter-involved accidents. A total of 108 instrumented tests were conducted for this purpose. The age of the test participants ranged from 4 years to 44 years.

Instrumentation

The dynamic test data was recorded by an electronic data acquisition system via sensors attached to the scooter. The collected data included time, distance and speed.

The Edelbrock QUIKDATA, electronic data acquisition system was used to collect the test data. The system was set at a sample rate of 500 hertz (500 samples per second) and a filter rate of five, resulting in a final data collection rate of 100 hertz (100 samples per second). The software with the unit provides a graphical display of the collected data and the ability to export to a spreadsheet program such as Excel.

The speed and distance sensor consisted of a reed switch and cobalt magnets. The reed switch has an operation time of 1.0 ms. The reed switch was mounted near the sidewall of the wheel and the magnets were bonded to the spokes of the wheel. As the wheel rotated, the magnet would pass by the reed switch and create a pulse. The pulse signal was sent to the digital channel of the data acquisition system and used as an accumulated measurement of distance and as a frequency for speed. The sensor was calibrated by measuring a distance of 91.436 meters (300.00 feet) with a Total Station, then rolling the scooter along that distance. Over the distance of 91.436 meters (300.00 feet), the final calibration of the sensor resulted in a reading of 91.41 meters (299.9 feet). A wheel with four magnets was used for the calibration to increase the resolution. During all the dynamic testing, wheels with two magnets each were used.

The data acquisition system, power supply and wire connectors were contained in a small nylon backpack that was worn by the test participant. A five-foot extension cable ran between each sensor and the data acquisition system. The combined weight of this equipment was approximately 2.80 kg (6.15 lb).

Scooter Specifications

The Razor™ scooter is constructed of aluminum, uses low-friction 100mm diameter polyurethane wheels with ball bearings and has a collapsible/folding handlebar. The brake system consists of an aluminum friction device that is applied to the rear wheel by the operator's foot.

The scooter used for the testing is designated as Razor™ model 130B1. This scooter has a front suspension and a slightly longer platform for the operator's feet than the model 103A. The construction of the model 130B1 was conducive to the routing of wires and the attachment of sensors.

Model	**Weight**	**Wheelbase**	**Test Weight**
130B1	**3.18 kg (7.0 lb)**	**55.9 cm (22 in)**	**3.36 kg (7.4 lb)**
130A	**2.73 kg (6.0 lb)**	**56.7 cm (22.3 in)**	

Coasting Downhill on a Constant Grade

In preparation of the downhill coasting test, participants were instructed to use one slight push with their foot at the beginning and then coast over a specified distance. Test participants were also instructed to maintain a fully upright "normal" body position. The test participants were dressed in jeans, sweatshirt and tennis shoes and also wore a helmet. The testing was conducted on asphalt roadways. Three different constant sloped roadways were used, with slopes of 6.9%, 9.0% and 15.0%. The tests were run over a distance of approximately 110 m (360 ft).

A series of graphs **(figures 1 through 6)**, demonstrate the results of the downhill coasting tests. The graphs have been normalizes to begin at a speed of 8.0 km/h (5.0 mph) as each participant's initial push and resulting speed was somewhat different. The graphs show the performance of the four different operators.

Operator	Height	Weight
A	**175.3 cm (69 in)**	**65.9 kg (145 lb)**
B	**151.1 cm (59.5 in)**	**43 kg (94.5 lb)**
C	**144.8 cm (57 in)**	**32 7 kg (72 lb)**
D	**123.2 cm (48.5 in)**	**22.5 kg (49.5 lb)**

Maximum Effort Acceleration

In preparation of the maximum acceleration tests, participants were instructed to use maximum effort to accelerate as quickly as possible and to the highest speed possible. The testing was conducted on a flat and level asphalt road surface.

As the operator accelerates the scooter, the operator used a series of strokes or pushes with the foot and leg. It was found that the stroke rate ranged from 1.1 to 2.0 per second with an average of 1.65 per second. There was no correlation of stroke rate and operator age. During each stroke the speed of the scooter would ramp up and down, with an overall net gain. During the stroke, the speed of the scooter varies by approximately 2.82 km/h (1.75 mph) above or below it's average speed.

A series of graphs **(figures 7 through 15)**, demonstrate the results of the maximum effort acceleration tests. The graphs indicate the performance of the operator based on age. The first group of graphs in the series shows the time it takes from the begin of acceleration to travel up to a distance of 1.0 meter (3.28 ft), 5.0 meters (16.4 ft), 10.0 meters (32.8 ft) and 20.0 meters (65.6 ft). The second group of graphs in the series shows the average speed of the scooter as it reaches the 1.0 meter (3.28 ft), 5.0 meters (16.4 ft), 10.0 meters (32.8 ft) and 20.0 meters (65.6 ft) positions. The last graph in the series shows the average of the sustained speed after accelerating.

Normal Effort Acceleration

In preparation of the normal acceleration tests, participants were instructed to accelerate in a normal manner and cruise at a normal speed. The testing was conducted on a flat and level asphalt road surface.

As the operator accelerates the scooter, the operator used a series of strokes or pushes with the foot and leg. It was found that the stroke rate ranged from 0.8 to 1.4 per second with an average of 1.1 per second. There was no correlation of stroke rate and operator age. During each stroke the speed of the scooter would ramp up and down, with an overall net gain. During the stroke, the speed of the scooter varies by approximately 2.06 km/h (1.28 mph) above and below it's average speed

A series of graphs **(figures 16 through 24)**, demonstrate the results of the normal effort acceleration tests. The graphs indicate the performance of the operator based on age. The first group of graphs in the series shows the time it takes from the begin of acceleration to travel up to a distance of 1.0 meter (3.28 ft), 5.0 meters (16.4 ft), 10.0 meters (32.8 ft) and 20.0 meters (65.6 ft). The second group of graphs in the series shows the average speed of the scooter as it reaches the 1.0 meter (3.28 ft), 5.0 meters (16.4 ft), 10.0 meters (32.8 ft) and 20.0 meters (65.6 ft) positions. The last graph in the series shows the normal average cruising speed of the operator.

Brake Performance

Test participants were instructed to bring the scooter up to a speed of 16 to 32 km/h (10 to 20 mph) and then apply the brake with maximum force while maintaining the scooter in an upright position. This testing was conducted on asphalt road surfaces. The brake system is designed to operate on the rear wheel only, consisting of an aluminum friction device that is applied when stepped on by the operator's foot.

During maximum application of the brake, it was found that a visible tire mark would appear on the road surface. In some cases, it is difficult to see and may require viewing with the sun coming from a particular angle. The contrast of the tire mark differs, depending on the coloring of the road surface. The initial length of tire mark is narrow and has a gray/black color. This tire mark is caused when the revolution of the rear wheel begins to slow. During this time, the friction between the road and tread cause a slight "cleaning" of the tread onto the road and/or deposit of the aluminum from the brake mechanism. During this same time, heat is generated due to friction at the brake to tread interface and also at the tread to road interface.

It was found that if the speed were high enough at the beginning of maximum brake application (usually at speeds of approximately 22.5 km/h (14 mph) or higher), then the tire mark would have a "second phase". During the "second phase", the tire has locked up and begins abrading on the road surface. This "second phase" tire mark is somewhat white in color with a tinge of coloring from the wheel material (i.e. a red wheel will produce a pink tinge). During this "second phase" skid, the scooter rear wheel may begin to slide out to the side.

Evidence that the rear wheel has locked up can be found by inspection of the rear wheel of the scooter. The wheel will develop a flat spot. The size of the flat spot will be a function of the dissipated kinetic energy, which is associated with speed and mass. At the trailing end of the flat spot, abraded wheel material particles can be found. Striation marks can be found on the flat spot and are an indication of the heading angle of the wheel. The angle of the flat spot surface with respect to the centerline of the axle is an indication of the lean angle of the scooter near the end of the locked wheel skid event.

The testing showed that the deceleration rate of the scooter during the initial tire marks and the "second phase" were approximately the same. In some tests the initial rate was slightly higher then the "second phase" and in other tests it was slightly lower. The average deceleration rate of the scooter was calculated using a speed at the beginning of the braking, a speed near the end of the braking and the associated distance.

Roadway Slope	Average Deceleration
0%	**0.263 g**
6.9% (downward)	**0.245 g**
9.0% (downward)	**0.228 g**

Drag Sled Testing

A drag sled was constructed using four scooter wheels, an aluminum frame and iron weights. The sled was constructed so that the wheels did not rotate. The total weight of the sled was 13.4 kg (36 lb). This sled was used to test the friction between the wheels and the road surface interface. As the drag sled was pulled parallel to the road surface, the force was measured using a dial indicator pull scale.

Typical measurements with the drag sled indicated friction values for an asphalt road surface in good condition to be approximately 0.8 to 0.87.

The results of the drag sled tests and the results of the scooter maximum brake tests were compared. This comparison indicates that the scooter decelerates at a rate equivalent to approximately 29.3 to 32.8 percent of the friction value determined by the drag sled test.

Weight Distribution

A series of static tests were conducted to measure the weight distribution of the scooter and operator upon the front and rear wheels. Digital scales were placed under each wheel to measure the weights at both the front and rear wheels. During the tests, the scooter was stabilized in a manner, which did not affect the weight registered on the scales.

In the first series of tests the participants were instructed to position themselves on the scooter, as they would be when coasting. The results determined a weight distribution of 37 to 39 percent on the front wheel and 61 to 63 percent on the rear wheel.

In the second series of tests the participants were instructed to position themselves on the scooter, as they would during brake application. The results determined a weight distribution of 8.7 to 33.3 percent on the front wheel and 66.7 to 91.3 percent on the rear wheel.

Discussion

The information contained in this paper provides a summary of data that can be used when reconstructing a scooter-involved accident. The data covers a range of different performance parameters and age of scooter operators. The testing for this paper was conducted on asphalt roadways as most scooter versus motor vehicle accidents will take place on an asphalt roadway surface.

Future testing will include maximum brake effort on concrete surfaces and also maximum brake effort on wet surfaces.

Questions and comments on the paper are welcomed and can be forwarded to:

Timothy J. Reust
Accident Science
27811 Avenue Hopkins, Suite #1
Valencia, California 91355

phone: (661) 257-8189
treust@accidentscience.com
www.accidentscience.com

Coasting On 6.9% Grade

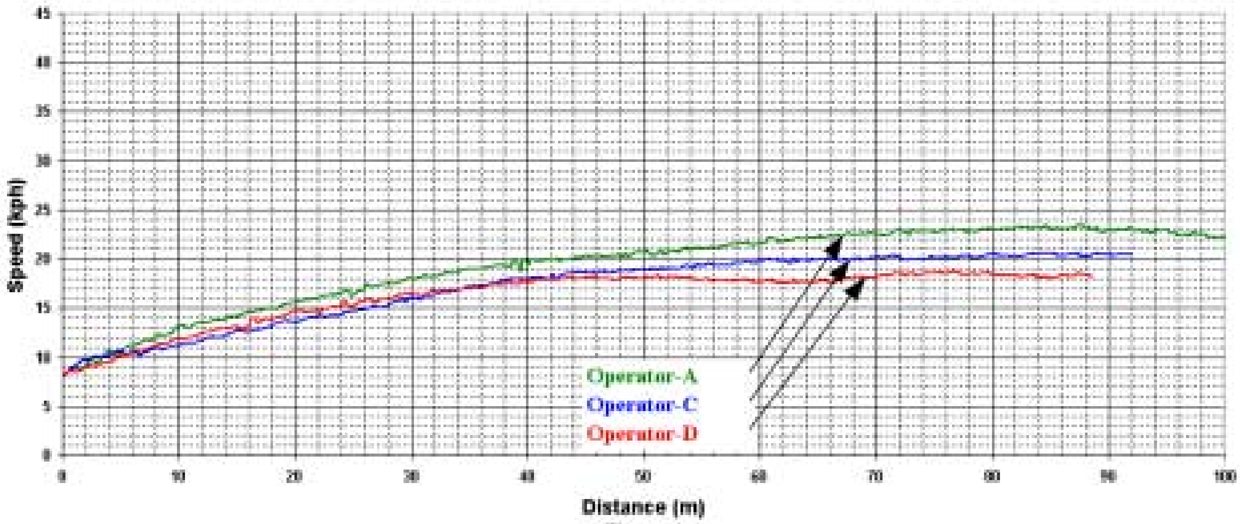


Figure 1

Coasting On 6.9% Grade From 8kph

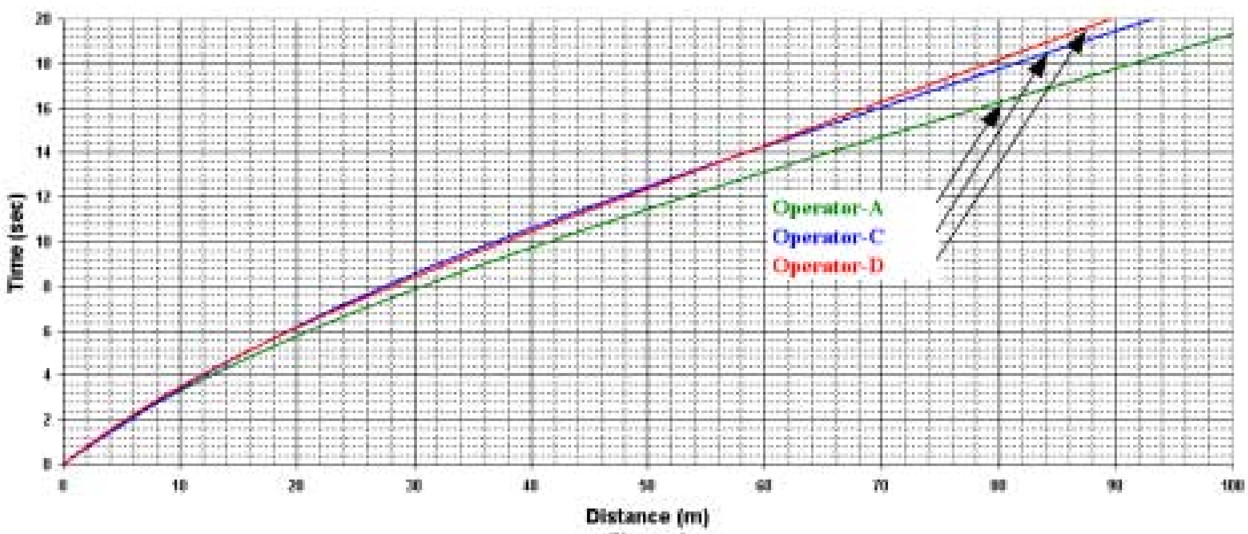


Figure 2

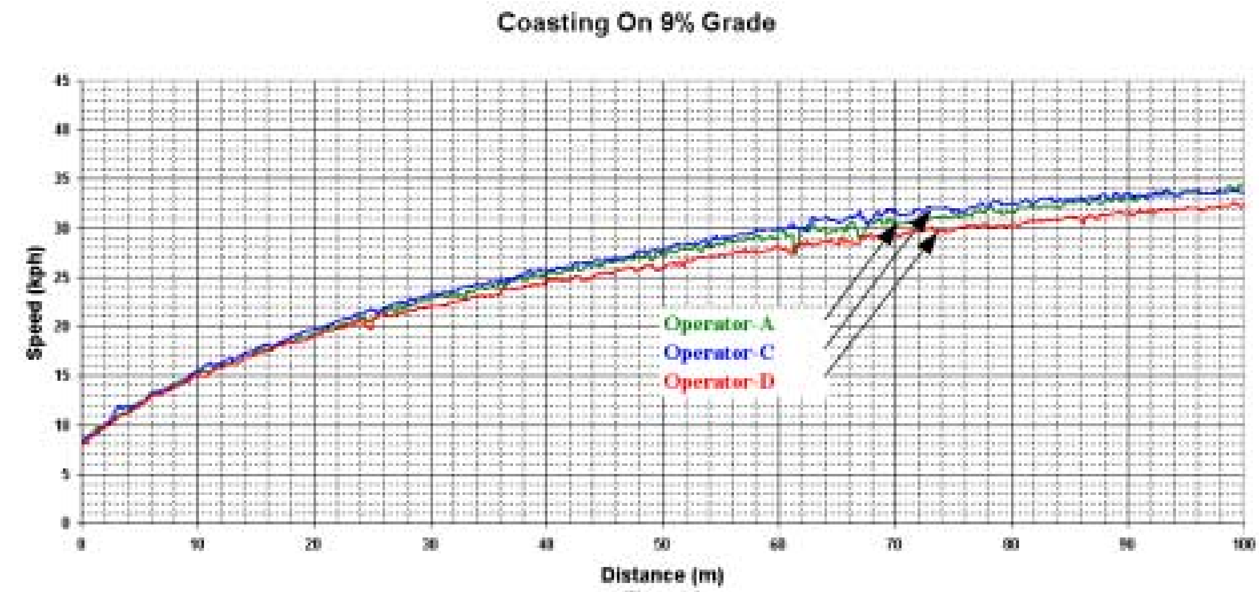


Figure 3

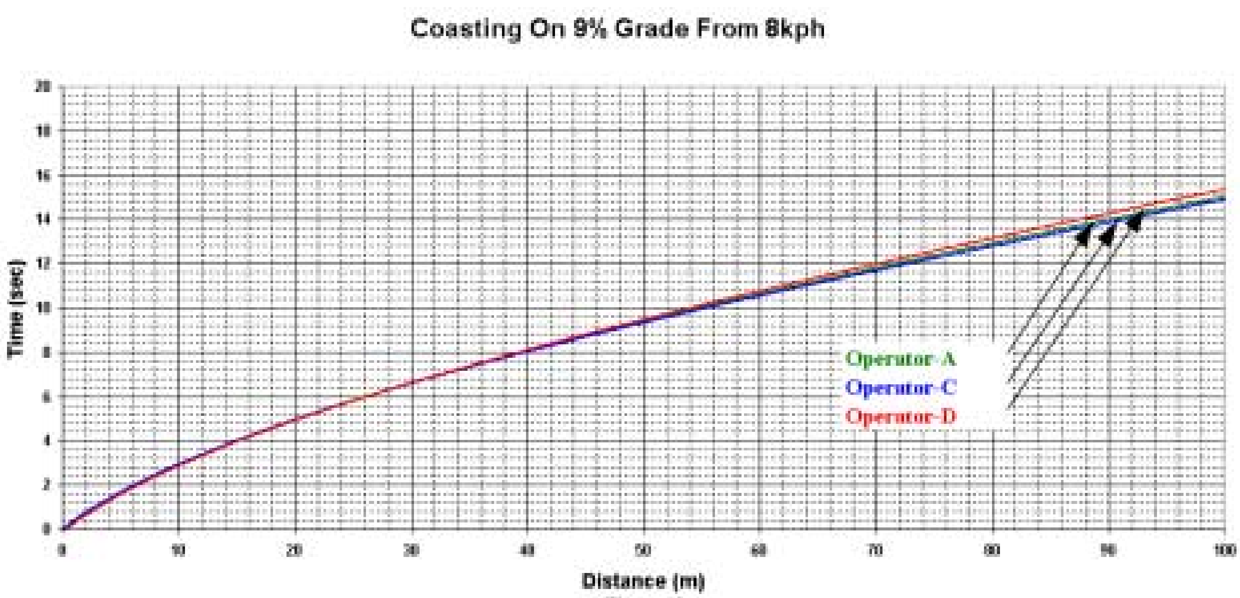


Figure 4

Coasting On 15% Grade

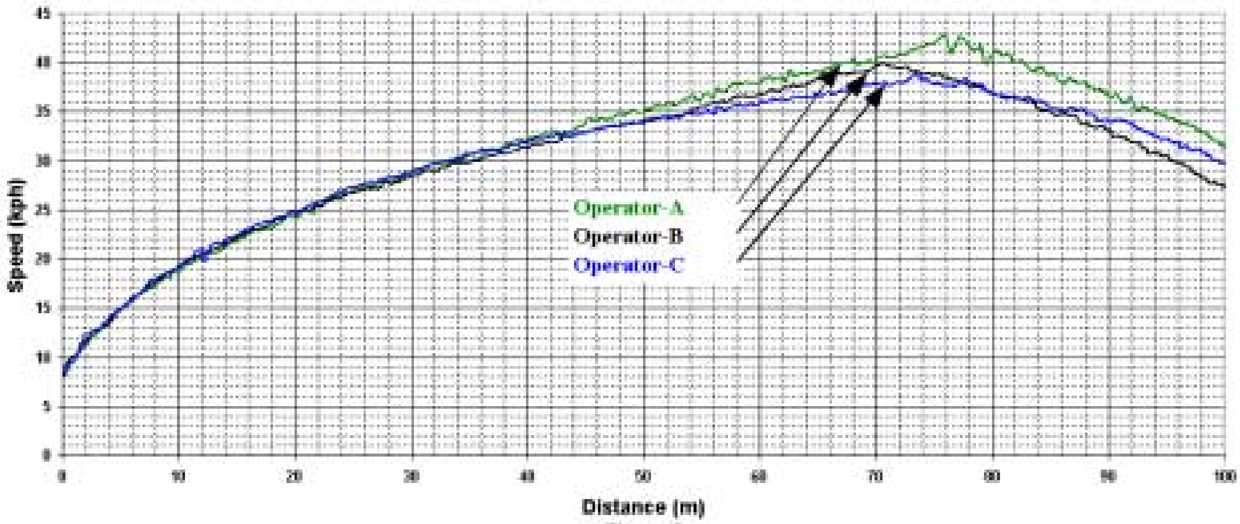


Figure 5

Coasting On 15% Grade From 8kph

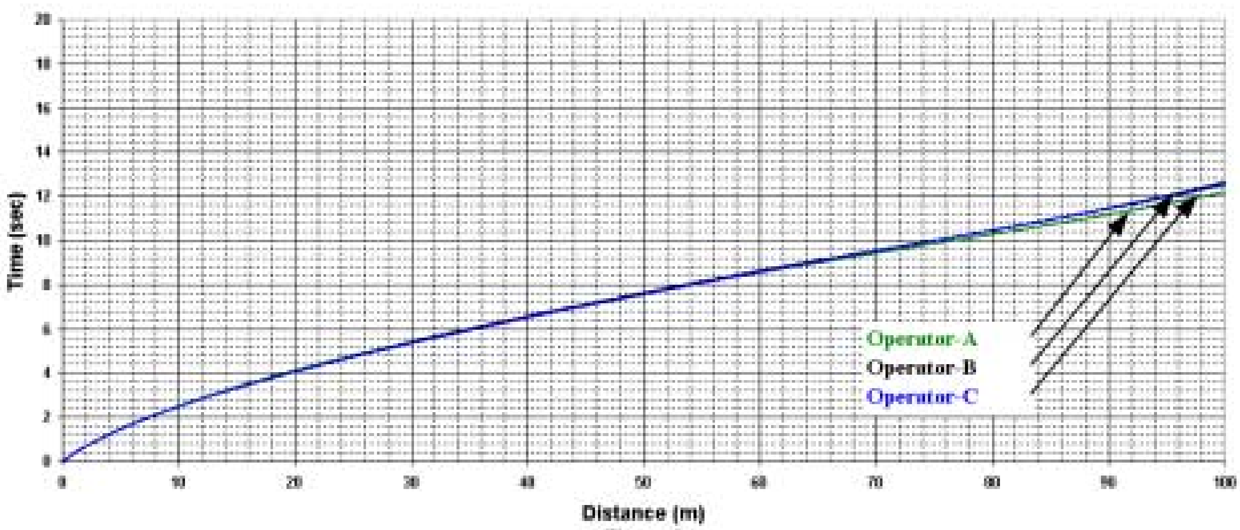


Figure 6

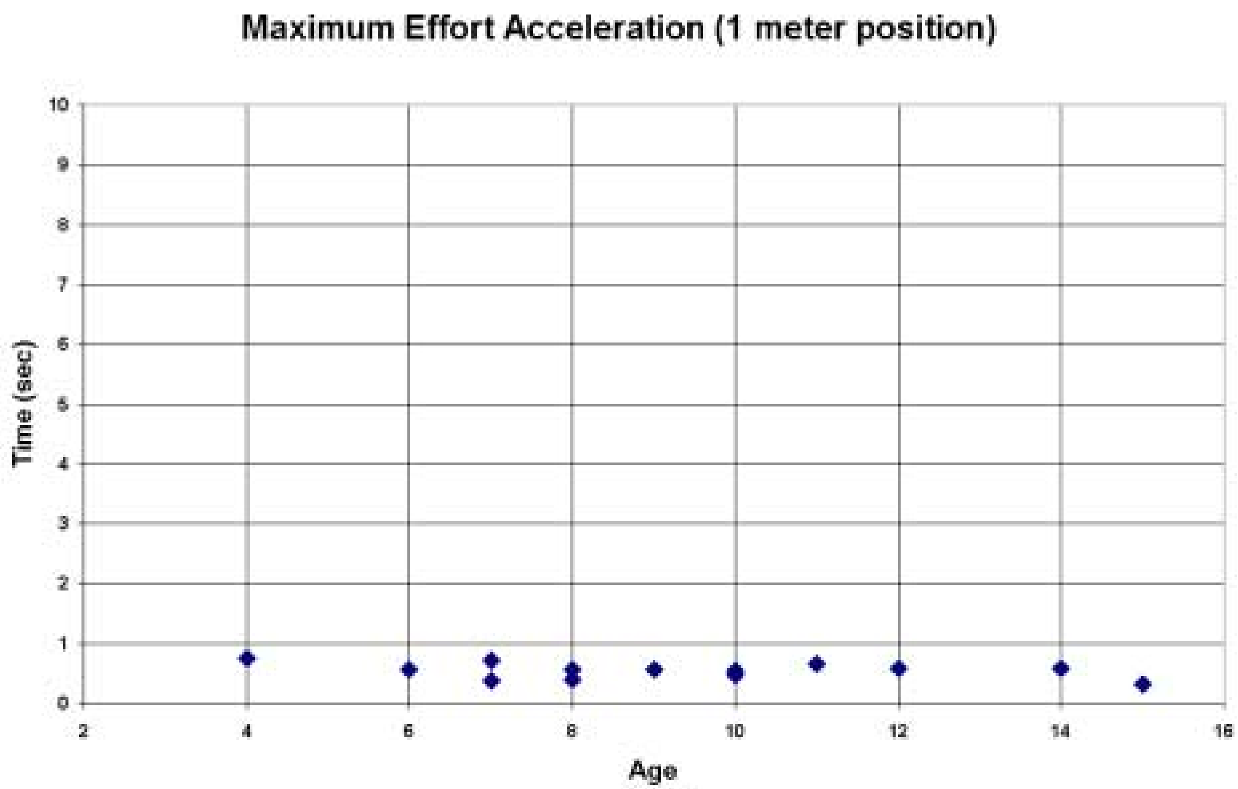
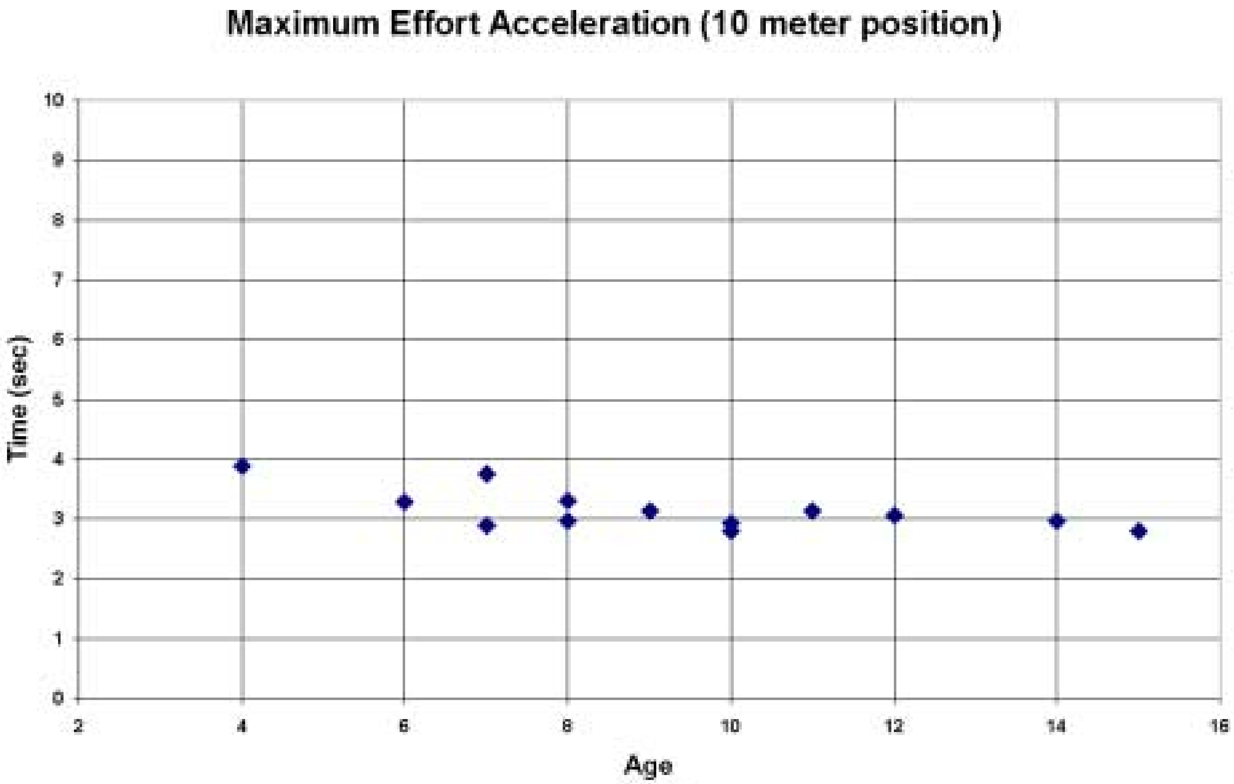
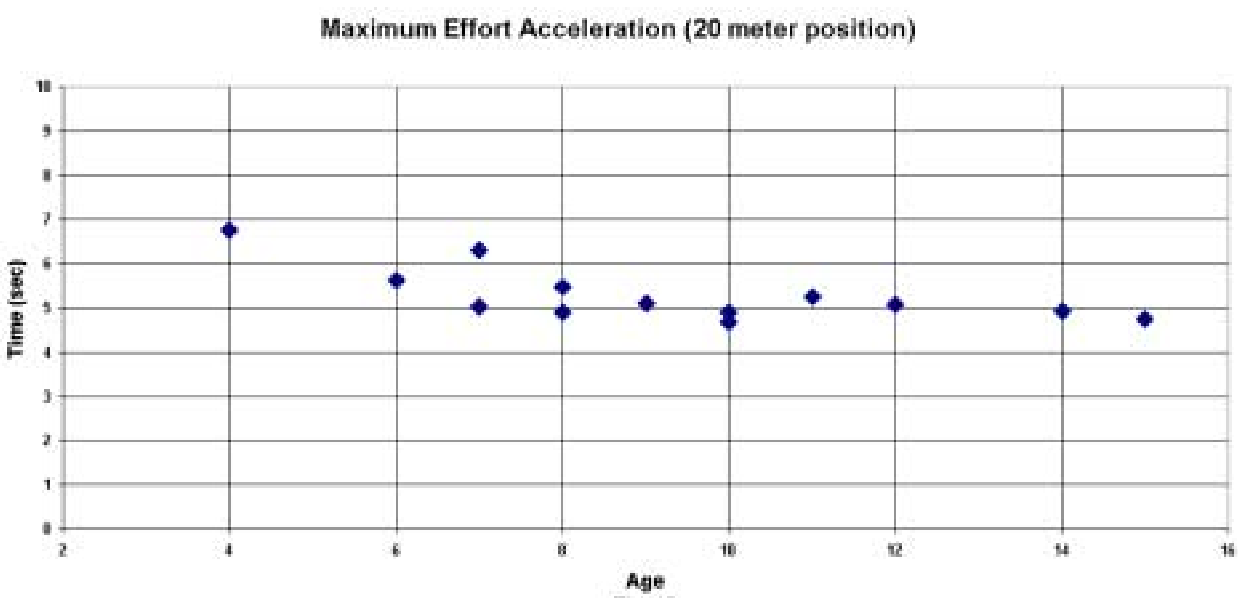

Maximum Effort Acceleration (1 meter position)
Time (sec)
Age

Fig. 7


Maximum Effort Acceleration (5 meter position)
Time (sec)
Age

Fig. 8


Maximum Effort Acceleration (10 meter position)
Time (sec)
0
1
2
3
4
5
6
7
8
9
10
2
4
6
8
10
12
14
16
Age
Fig. 9


Maximum Effort Acceleration (20 meter position)
Time (sec)
Age
Fig. 10

Maximum Effort Acceleration (1 meter position)

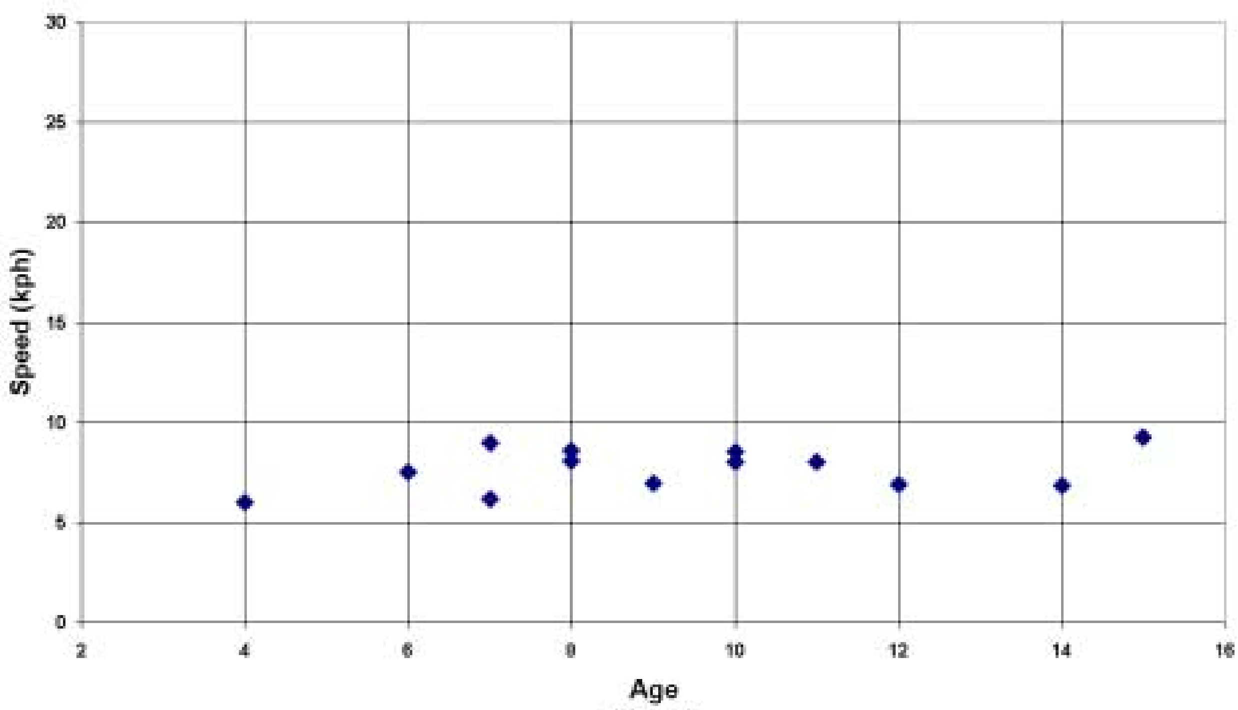

Speed (kph)
30
25
20
15
10
5
0
2
4
6
8
10
12
14
16
Age

Fig. 11

Maximum Effort Acceleration (5 meter position)

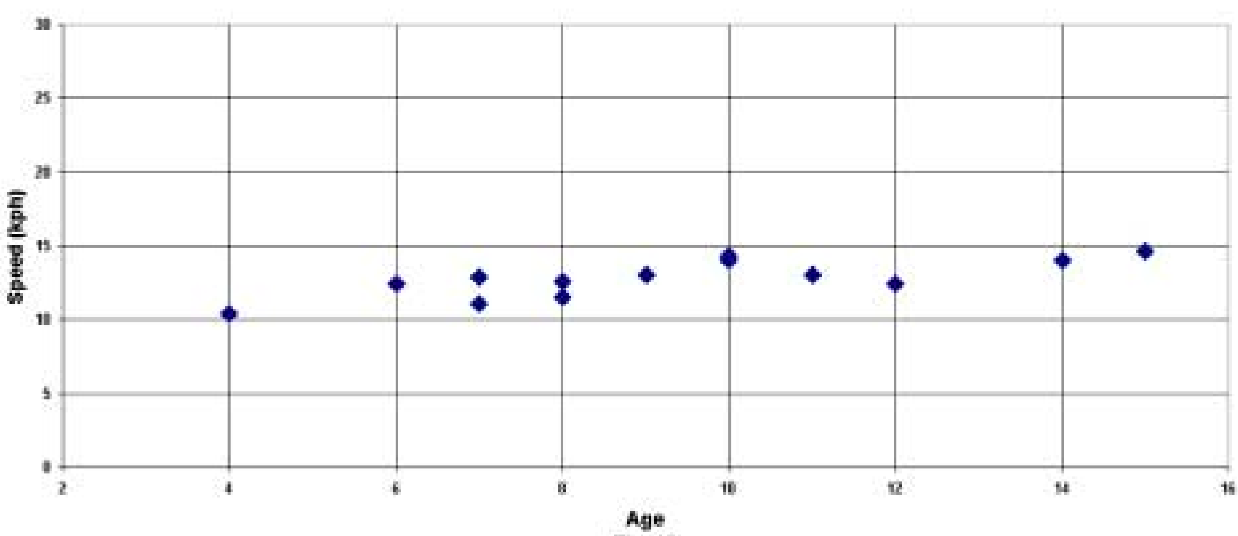

Speed (kph)
Age

Fig. 12

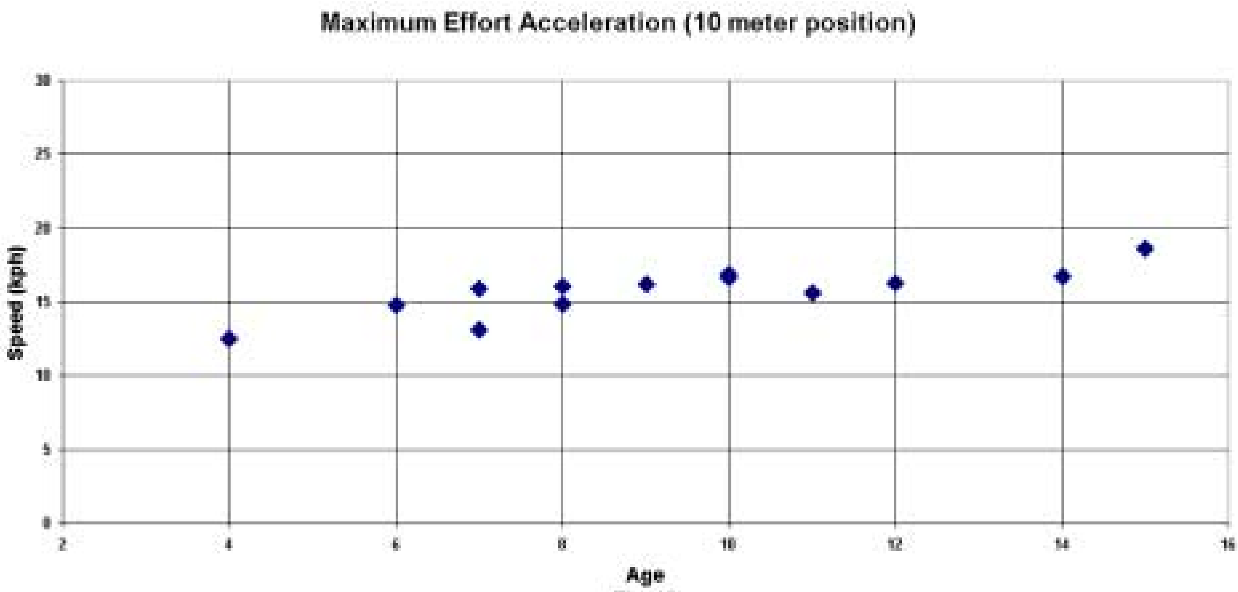

Maximum Effort Acceleration (10 meter position)
Speed (kph)
Age

Fig. 13

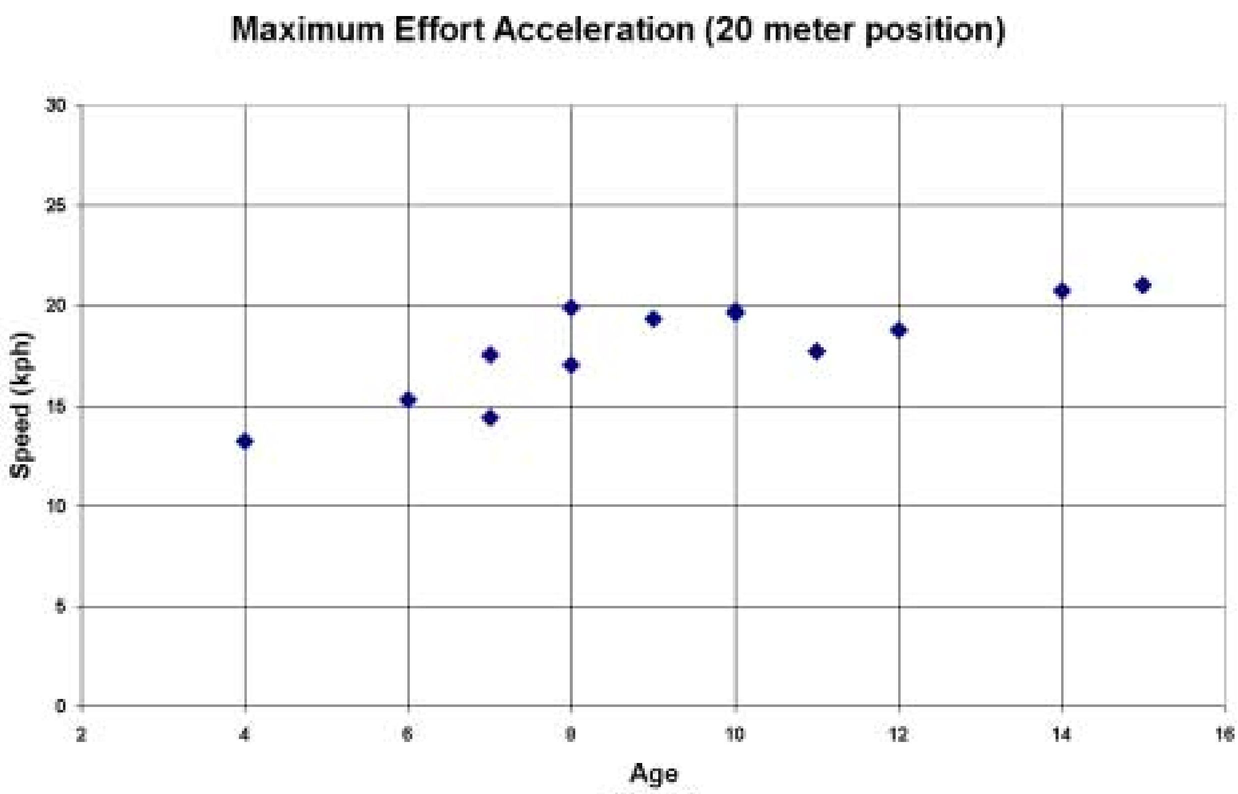
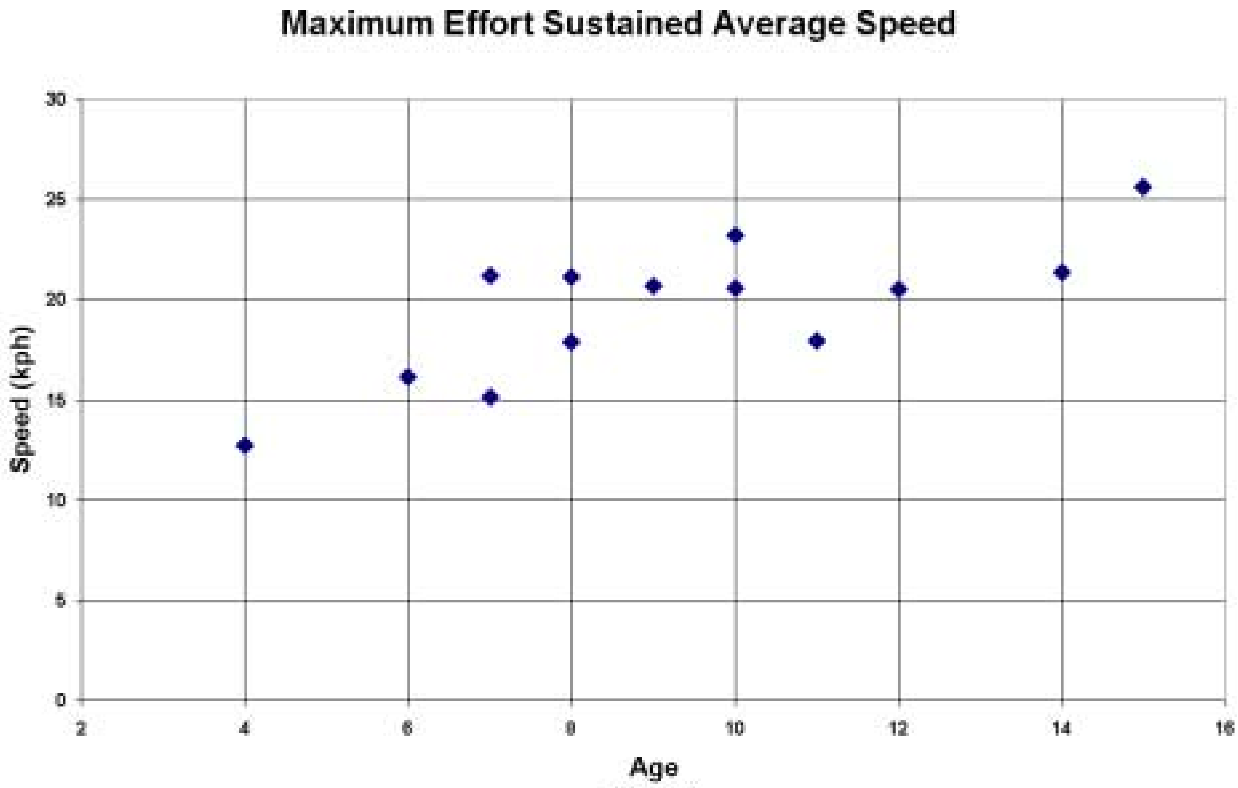
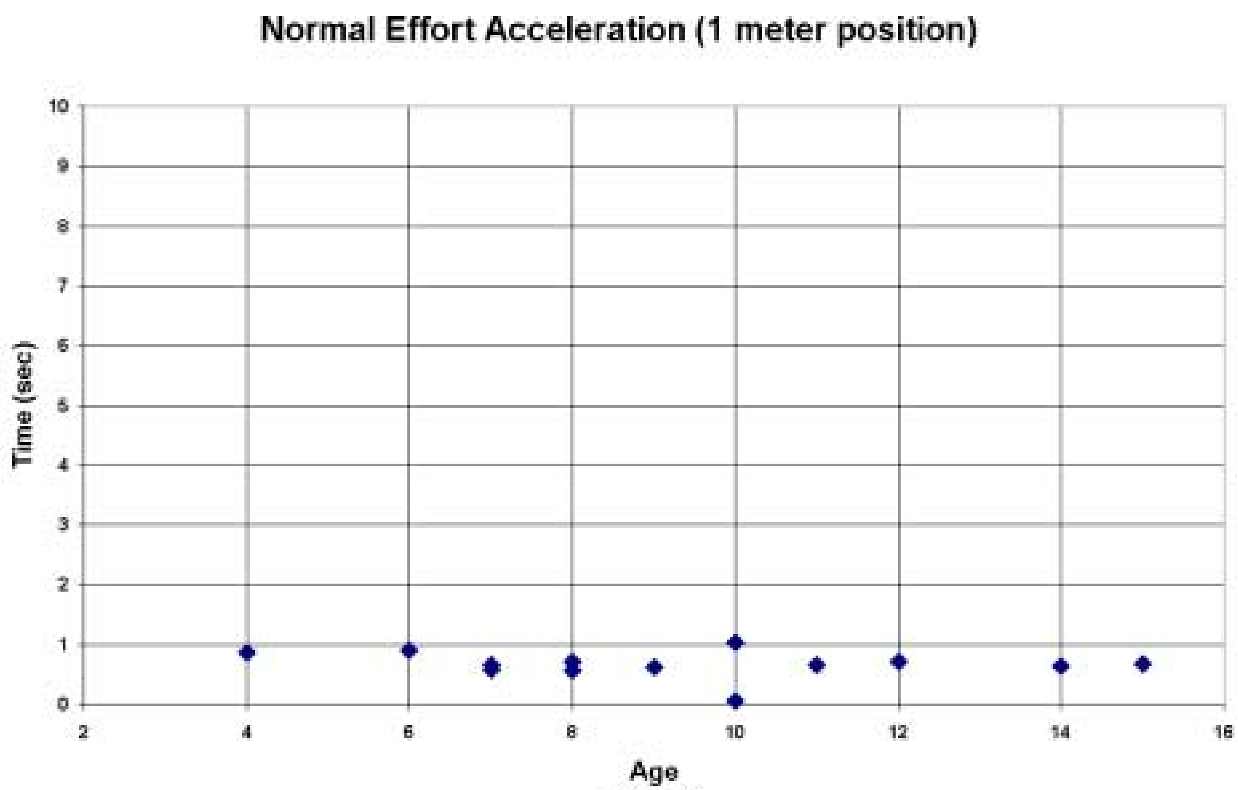

Maximum Effort Acceleration (20 meter position)
Speed (kph)
30
25
20
15
10
5
0
2
4
6
8
10
12
14
16
Age

Fig. 14


Maximum Effort Sustained Average Speed
Speed (kph)
Age
30
25
20
15
10
5
0
2
4
6
8
10
12
14
16
Fig. 15


Normal Effort Acceleration (1 meter position)
Time (sec)
Age
10
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
16
Fig. 16

Normal Effort Acceleration (5 meter position)

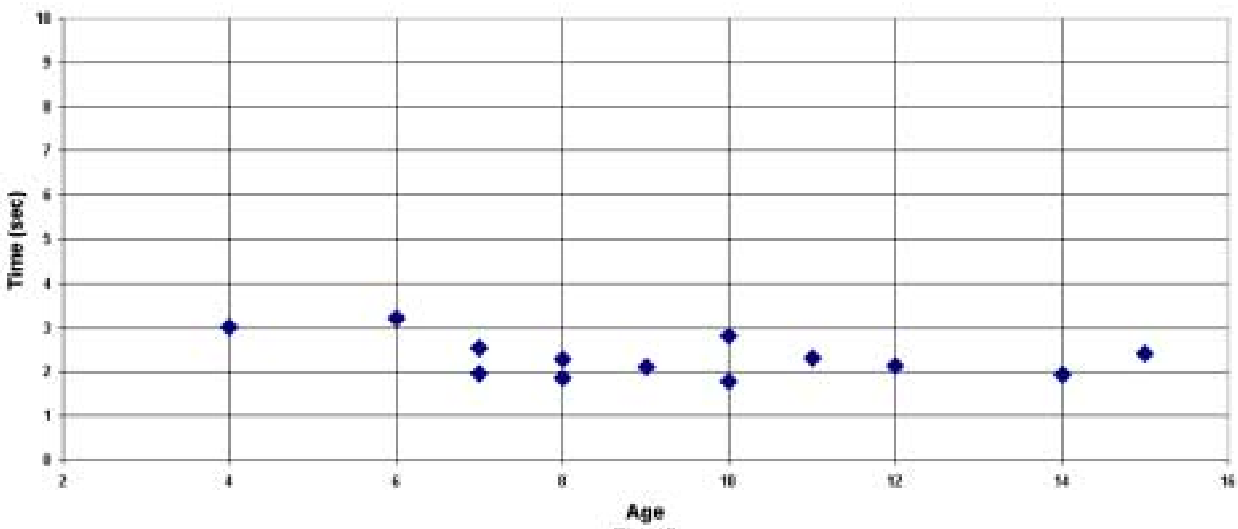


Fig. 17

Normal Effort Acceleration (10 meter position)

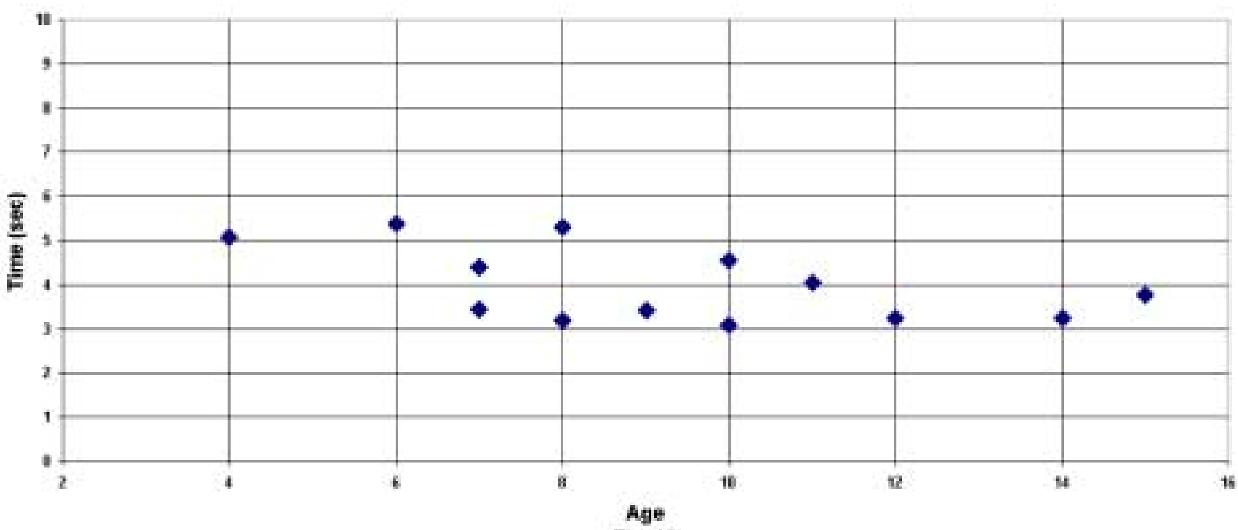
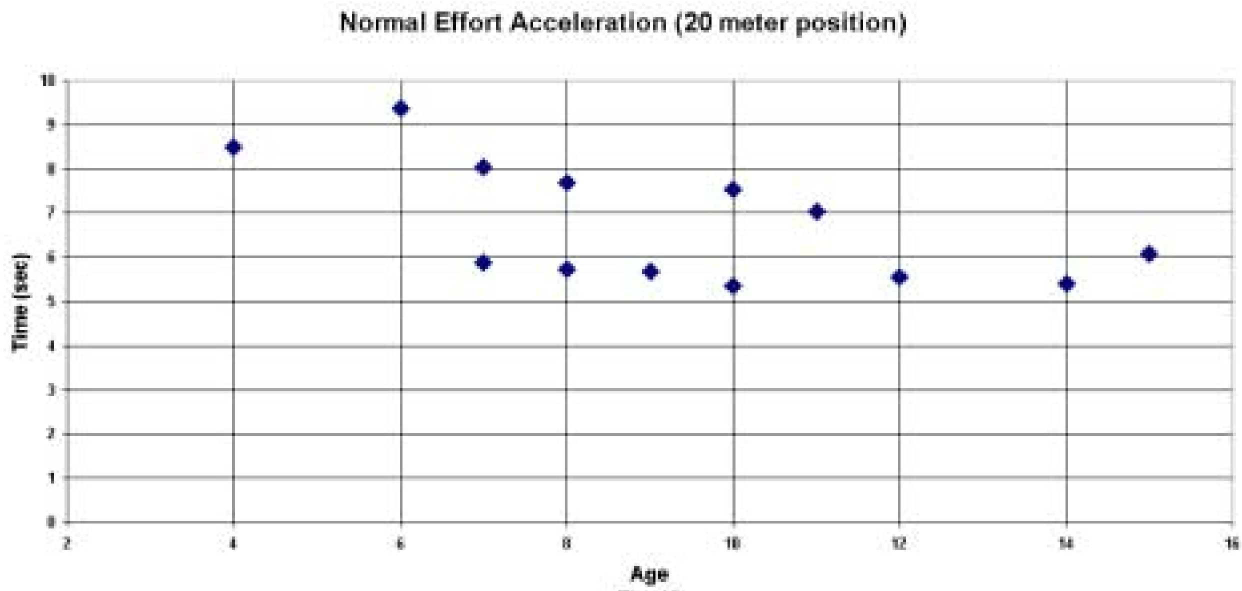
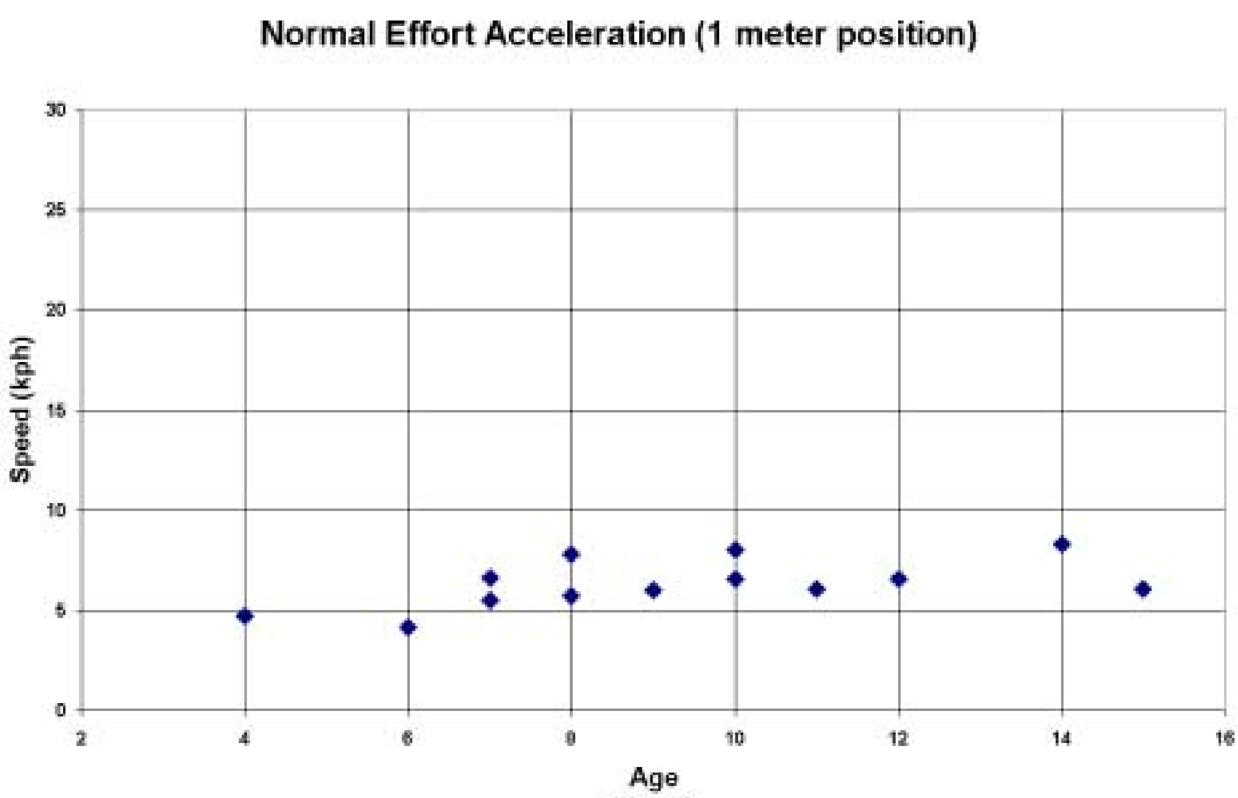


Fig. 18



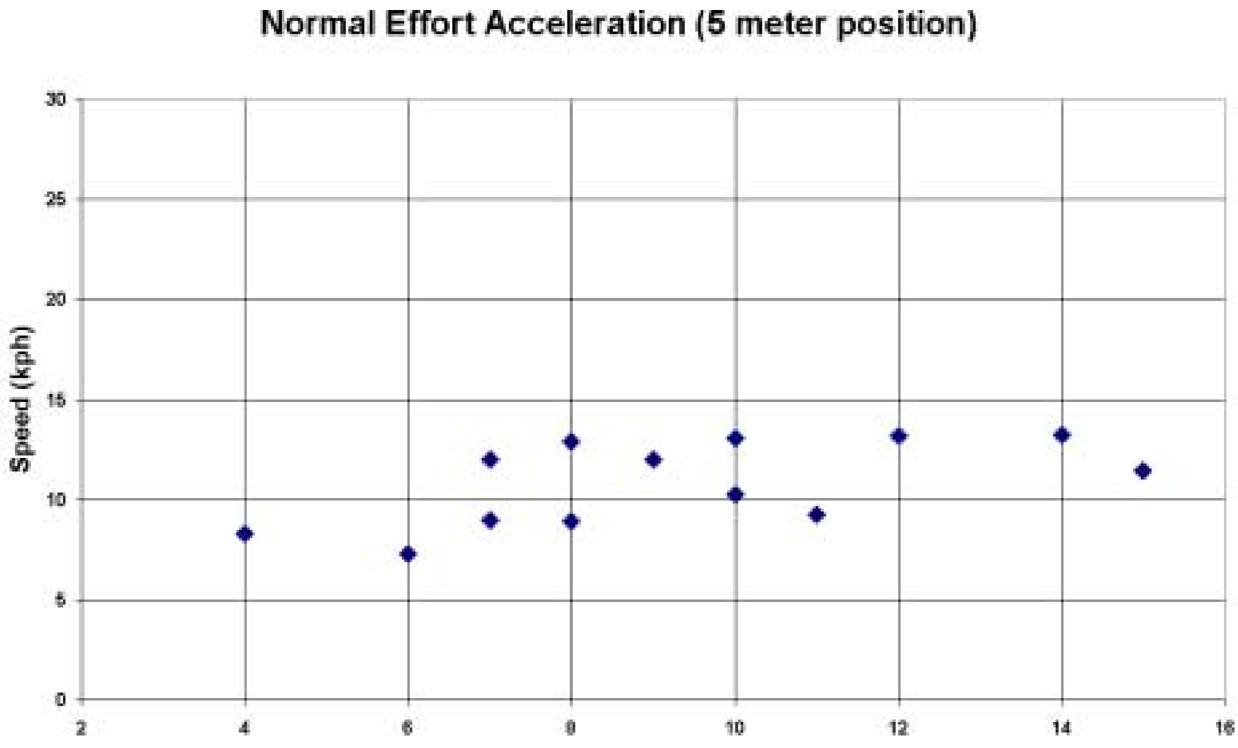
Normal Effort Acceleration (20 meter position)
Time (sec)
Age

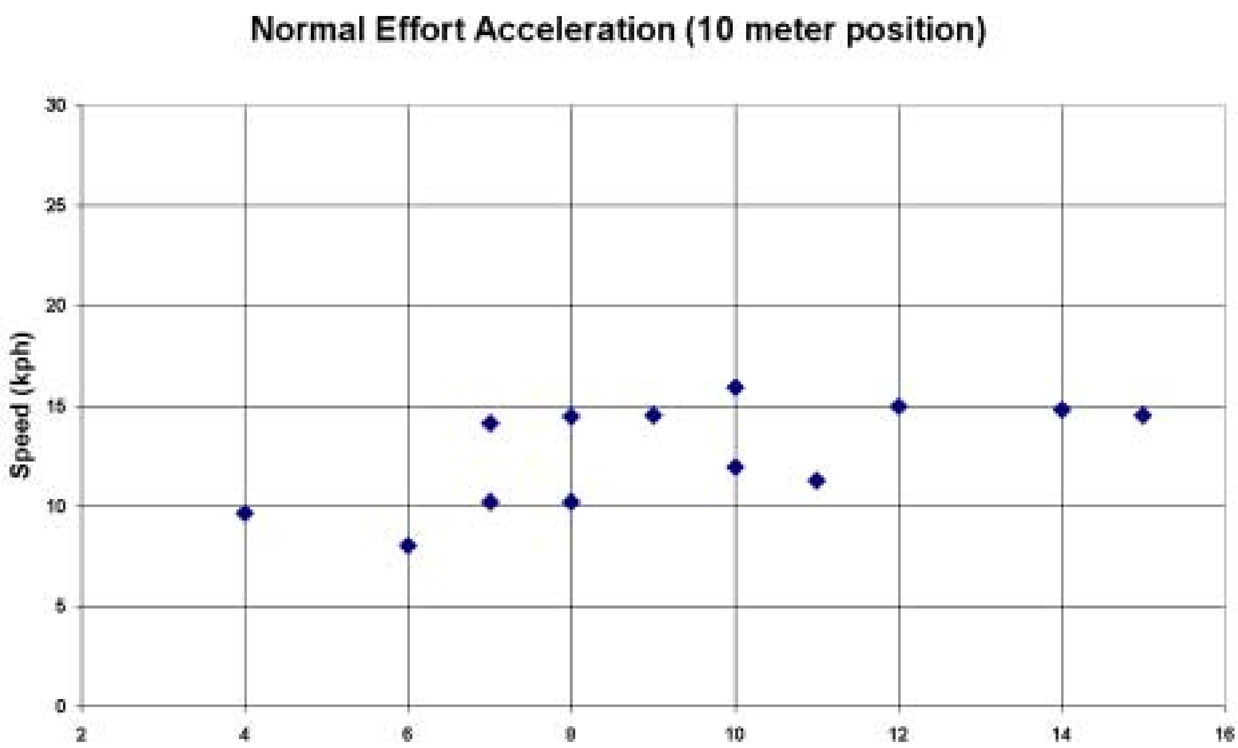
Fig. 19

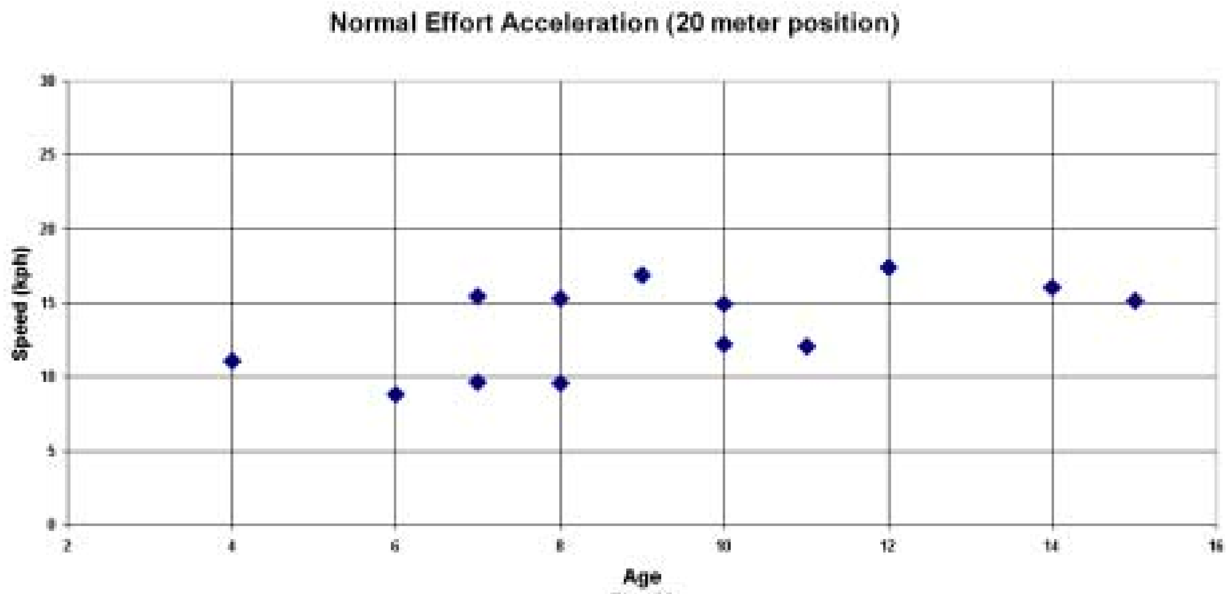


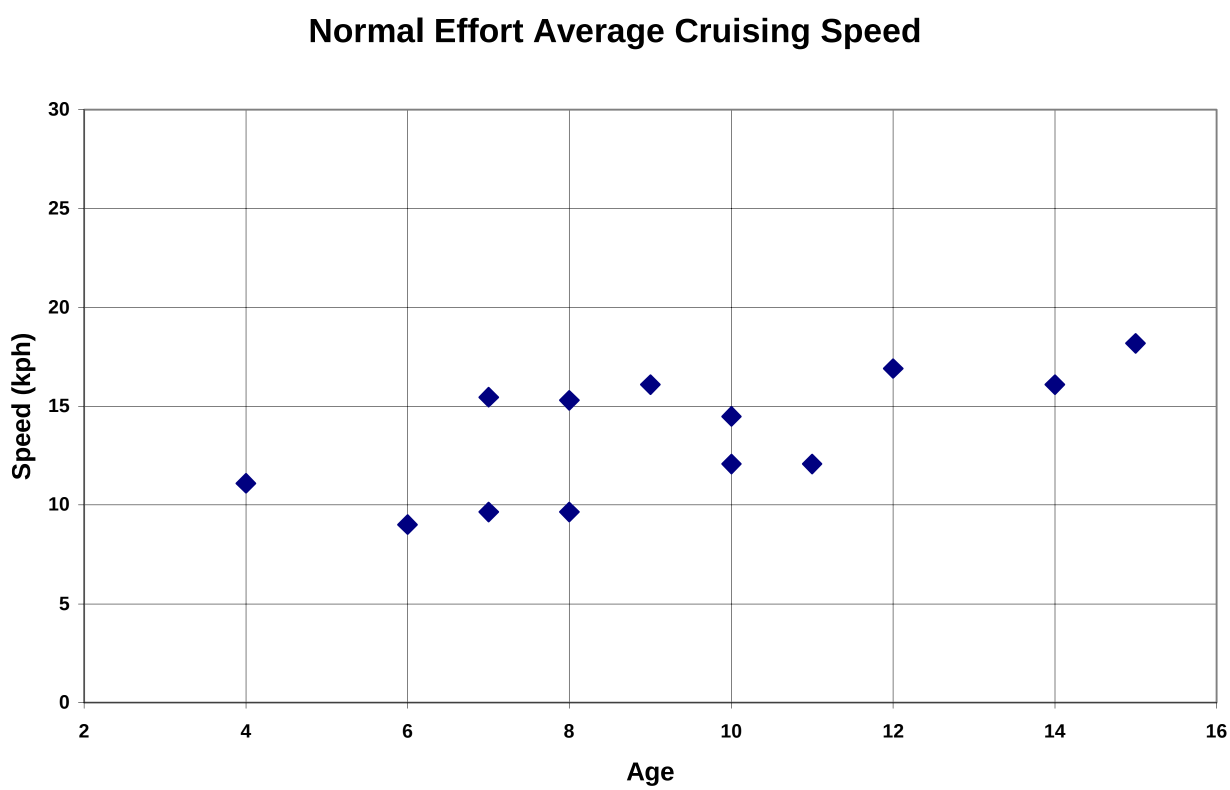
Normal Effort Acceleration (1 meter position)
Speed (kph)
30
25
20
15
10
5
0
2
4
6
8
10
12
14
16
Age

Fig. 20


Normal Effort Acceleration (5 meter position)
Speed (kph)
Age
0
5
10
15
20
25
30
2
4
6
10
12
14
16
Fig. 21


Normal Effort Acceleration (10 meter position)
Speed (kph)
Age
0
5
10
15
20
25
30
2
4
6
10
12
14
16
Fig. 22


Normal Effort Acceleration (20 meter position)
Speed (kph)
Age
Fig. 23


Normal Effort Average Cruising Speed
Speed (kph)
0
5
10
15
20
25
30
2
4
6
8
10
12
14
16
Age
Fig. 24