PRELIMINARY EVALUATION OF A PRECISE STARTING SENSOR FOR SHORT DISTANCE ATHLETIC SPORTS BELOW 400 m

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The importance of starting a race in short distance athletic sports below 400 m was rarely considered to the extent that it should be. The main research theme in this field has mainly been the relationship between the starting signal and the response speed of leg muscles. The records in short distance athletic sports have been improved through training athletes to increase their response speed. However, the improvements in records have also been due to the starting time speed; thus, there is another way to improve times, that is, through the starting speed. The starting speed related to the kicking force against the starting blocks at the start of a race. The objectives of this research were to present a method for analyzing forces acting upon a starting block at the start of a race and to optimize the starting conditions for each athlete. To achieve these objectives, a starting block with Wheatstone bridge type strain gauges which could measure, in normal and horizontal directions, the repulsive forces acting on the starting blocks at a starting point in real-time, was developed. The use of this block was expected to correct the posture of each athlete and record the sports dynamics data for each athlete.

KEY WORDS: starting block, strain gauge, athletic.

INTRODUCTION: The importance of starting in short distance athletic sports below 400 m has begun to be recognized for a long time. Currently, starting blocks are used as tools to make starting easier in every race of short distance athletic sports and, in effect, to improve records. The starting block helps increase the kicking force of athletes' feet. It is possible to control the lengths and angles of starting blocks according to individual athletes to improve their starting speed. Due to the structure of starting blocks, before track athletes start a race, no forces are applied to the footboard. When the athletes start, they push the footboard with their feet. Kicking forces to the footboard are distributed vertically to the longitudinal direction of the footboard. Also, forces are exerted on connection parts that support and fasten the footboard. Forces that are exerted on the connection parts are distributed horizontally to the surface, (Aron et al, 2003; Bret et al 2003). This study presents a method to analyze forces that affect starting blocks at the start of a race and which will, ultimately, help each athlete to determine his or her optimal starting conditions. In short distance track races, the start is the most important point of the race. For this study, existing starting blocks were used. These starting blocks help athletes reach their maximum speed by using the greatest amount of power and physical balance along with the smallest amount of energy in the shortest period of time. Repulsive force sensors were developed and attached to the starting blocks according to their sizes. These sensors will correct the postures of short distance track athletes at the starting line and measure the repulsive forces of each athlete, thus contributing to record improvements. The purpose of this study is to provide equipment that can measure the exact starting time of an athlete by installing a sensor to the parts of starting blocks where forces are applied and where they change.

METHODS: As shown in Figure 1, starting blocks are composed of the footboard that an athlete's feet meet and fixed ends that fix the footboard to the ground by the anchor. The vertical direction force (F_t) to the footboard occurs orthogonally to the plane of the footboard. This vertical direction force (F_t) is measured by a normal sensor. The connection part receives the horizontal direction force (F_x) from the kicking force to the footboard. The horizontal direction force (F_x) is measured by a horizontal sensor.

By measuring this vertical direction force (F_t) and horizontal direction force (F_x), the gravitational direction force (F_z) that allows an athlete to stand can be calculated. The angle (θ) that is formed by vertical direction force (F_t) and horizontal direction force (F_x) is the same as the one formed by the orthogonal direction (θ) of the plane of the footboard, the ground of the support, and the horizontal direction. Therefore, according to Pythagoras's theorem, gravitational direction force (F_z) is calculated as Formula (1), shown below.

$$F_t^{\,2} = F_x^{\,2} + F_z^{\,2} \qquad (1)$$

The footboards consist of Board One, where the right foot is placed, and Board Two, where the left foot is placed. The components of the footboards are a connection part in the bottom, control equipment that adjusts the angle between the footboard and the ground, another connection part, and a normal sensor installed in the footboard. There are holes in footboards so the angle can be adjusted by inserting pins in the holes and grooves.
The binding equipment is installed in the upper part of the connection part, the salient part, and in the bottom of the connection part. The binding equipment consists of a thread, and a bolt connects the connection part with the binding equipment.
The normal sensor and the horizontal sensor consist of strain gauges. Eight strain gauges are needed for the normal sensor. The eight strain gauges consist of Compression Strain Gauge One, Two, Three, and Four, which are all located on the top, and Tension Strain Gauge One, Two, Three, and Four, which are located on the bottom. The compression strain gauge is located on the top corner, and the tension strain gauge is located at the bottom corner (Figure 2).
There are four strain gauges of the horizontal sensor in the connection part. The four strain gauges consist of the first tension strain gauge, positioned in a part of the connection part; the first compression strain gauge; the second tension strain gauge, positioned in the other part of the connection part; and the second compression strain gauge. The tension strain gauge is installed on the part that receives tension through forces that are applied horizontally to the connection part, and a compression strain gauge is installed to the part that is compressed by forces that are applied horizontally.

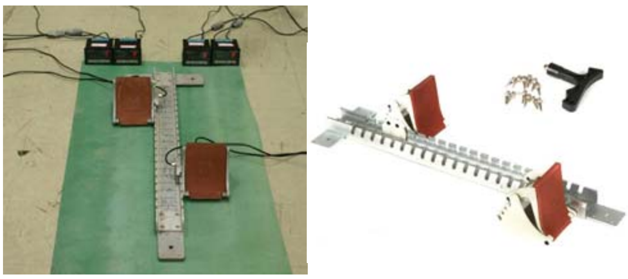

Figure 1: Starting block with sensors

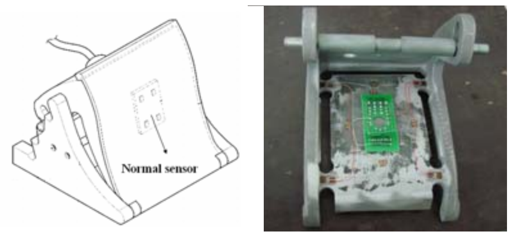

Figure 2: Normal sensor

Each strain gauge is connected as a part of a Wheatstone bridge circuit. In the Wheatstone bridge circuit of the normal sensor, the first compression strain gauge, the second compression strain gauge, the third compression strain gauge, and the fourth compression strain gauge, along with the first tension strain gauge, the second tension strain gauge, the third tension strain gauge, and the fourth tension strain gauge on the other hand are connected serially. Specifically, the first compression strain gauge and the second compression strain gauge are connected to the third and fourth compression strain gauges face to face. Meanwhile, the first and the second tension strain gauges are connected with the third and fourth strain gauges face to face.
In the Wheatstone bridge circuit of the horizontal sensor attached to the connection part, the first and the second compression strain gauges are connected face to face and the first and the second tension strain gauges are connected face to face as well.

The signal process equipment is composed of an amplifier connected to a galvanometer, a display part that is connected to the amplifier with connection equipment that shows output voltage, and analysis equipment that detects the starting time by analyzing display parts.

RESULTS AND DISCUSSION: A galvanometer measures the output voltage from the normal sensor attached to the footboard, and the output stage of the Wheatstone bridge circuit connected to the connection part. At the start, when forces are applied, the output voltage changes, and the amplifier amplifies this output voltage. The amplifier is connected to the display part with the connection equipment. Horizontal to the connection part, and a compression strain gauge is installed on the part that is compressed by forces that are applied horizontally (Figure 3).

As shown in the analysis equipment, the time when forces are applied is found and starting time is established. The display part shows output voltage and thus, when an athlete uses force to start a race, output voltage drastically changes. By measuring the change in time, the exact starting time of the athlete can be determined.

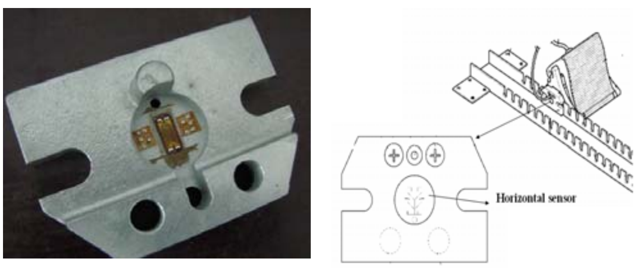

Figure 3: Horizontal sensor

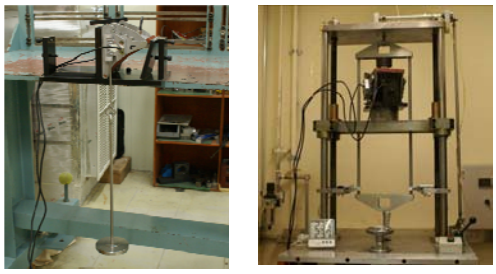

Figure 4: Calibration procedures

The starting block described above is anchored. As shown in figure 4, the produced sensor is anchored by a deadweight force standard machine and weight. All equipment is compressed and fixed using “the Standard Calibration Procedure of Electric Force Measuring Devices” and the Relative Expanded Uncertainty of the standard was within 0.005 % (a confidence level of approximately 95 %, *k*=2) [4]. The relative expanded uncertainty (REU) of each piece of equipment was calculated as shown in tables 1 and 2, which REU was defined as $W_p = k \cdot w_c (\%)$, *k*=2 (95%) [5]. By using this equipment, any data that applies to the athlete may be acquired.

Table 1 Data of the relative expanded uncertainty (left foot)

(a)F_n Compression			**(b) F_x Compression**		
Real weight (N)	Relative expanded Uncertainty(REU) (W_i, %)	Uncertainty into force (Column 1 * column 2) (N)	Real weight (N)	Relative expanded Uncertainty(REU) (W_i, %)	Uncertainty into force (Column 1 * column 2) (N)
0	0	0	0	0	0
300	2.267	6.67	50	3.456	1.69
500	1.870	9.17	100	3.031	2.97
1000	1.205	11.81	150	2.189	3.22
1200	1.126	13.24	200	2.066	4.05
1500	1.060	15.59	250	1.526	3.74
2000	0.705	13.81	300	1.017	2.99
2500	0.318	7.78	350	0.688	2.36
3000	0.104	3.05	400	0.472	1.85

Table 2 Data of the relative expanded uncertainty (right foot)

(a) F_n Compression			(b) F_x Compression		
Real weight (N)	Relative expanded Uncertainty(REU) (W_i, %)	Uncertainty into force (Column 1 * column 2) (N)	Real weight (N)	Relative expanded Uncertainty(REU) (W_i, %)	Uncertainty into force (Column 1 * column 2) (N)
0	0	0	0	0	0
300	1.930	5.68	50	3.920	1.92
500	1.618	7.93	100	3.405	3.34
1000	1.586	15.55	150	2.440	3.59
1200	1.183	13.92	200	1.972	3.86
1500	0.800	11.76	250	1.695	4.15
2000	0.436	8.55	300	1.014	2.98
2500	0.238	5.82	350	0.538	1.84
3000	0.073	2.13	400	0.148	0.59

CONCLUSION:

Through this study, a sensor system that uses Wheatstone bridge type strain gauges was created to measure repulsive forces in vertical and horizontal directions that are applied to starting blocks at the start of short distance athletic races. The equipment produced shows a maximum of 4% repeatability and uncertainty in each of the operating forces. It is expected that the actual results of athletes will be acquired using the proposed equipment and that these results will help to determine the optimal stance of each athlete.

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