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# Balance as quality of motory-sports performance in a target evaluation between advanced technology/IMU

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**Abstract**
Motor control and consequently balance is a fundamental ability in sports performance, from the most simple movement to a complex dynamic movement, from all of those every sport movements are born. The purpose of this study is to monitor the static and dynamic balance through the Stork Test with the use of K-Track (K-Sport Universal, Italy) a high precision Inertial Measurement Unit (IMU), thanks to its latest generation components with frequency rate of 200 Hz. The proposed study analyzes the development of pre-adolescent equilibrium on a under 13 amateur football team (Italian) composed of 18 subjects (Age 11.5 ± 1, Height 1.51 cm ± 10.5, Weight 48 Kg ± 8.3) with a PRE-POST protocol. This study was possible thanks to the Advanced Research Group of the School of Sport and Sport Sciences at Carlo Bo di Urbino University, Italy and K-Sport Universal (ITA).

**Keywords:** Motory-sports performance, target evaluation, advanced technology

## Introduction
As we all know, sport performance is basically determined by motor skills every human movement, from the simplest to the most complex, is mediated by these abilities, which affects its success and economy [1]. In the past, it wasn't possible to quantify these capabilities in a precise way, but over the last few years become possible detect them through use of advanced technology systems). A systematic acquisition and monitoring of objective data can be decisive in the field of motor control and of young athletes. Being able to evaluating quantity and quality of human movement is important both in physical education, on health care and in rehabilitative field. Constant and programmed acquisition will therefore be useful in order to be able to control the progress of young subjects, to hollowing them during individual growth rate. To perform tests in youth categories, it is necessary to use a simple and clear language, tests must provide to young people with a pleasant and positive opportunity to discover their own body, while for the interpretation of results, it is crucial to distinguish the influence of chronological age/growth rate. This will represent the actual maturity level and personal property of each individual subject and is defined by the values of body segments, bone age, and secondary sex characters [3]. Therefore subjects of the same chronological age may also have differences in biological age up to 5 years. Studies on a large number of subjects aged between 11 and 18 years showed that the biological age of the sample was 62% higher then their chronological age [4]. Tests on youth categories are performed with the aim of to obtain data on growth rate and development, thus having the potential to detect any anomalies and to prevent any kind of risks. Control the sensitive phases are particularly useful and important in those categories, where those periods of development are highlighted in which there is a greater predisposition to the learning of certain motor skills and sports abilities [5].

## Means and Methods
The purpose of this study was to evaluate the motor and balance control capacity, for this purpose was used the Stork test [6] using the K-Track device (K -Sport Universal, Italy), wearable technology that incorporates inertial micro-sensors of the latest generation, such as an accelerometer, a gyroscope and a magnetometer with frequency rate at list of 200 Hz, which allow to evaluate performance without altering it, because the weight of the device is irrelevant (25g). (Figure 1).


**Fig 1:** K-Track Case

The IMU's measures the acceleration in the antero-posterior (AP) direction along the sagittal axis in the direction mid-lateral (MD) along the transverse axis and in the direction V (vertical) along the longitudinal axis. By combining information we will have precise indications of which positions took the body on the three planes [7], specifically combining the directions:

- AP and ML, assumed on the transversal plane;
- AP and V, position assumed on the sagittal plane;
- ML and V, front position occupied.

The acceleration values analyzed by K-Track on all three axes give us important insights on the stability of the inspecting exercise. The values found on the axes are expressed in m/ s2 in the X axis to indicate right (positive values) or left (negative values), thus representing a lateral oscillation of the athlete on the Y axis, the values turn upwards (positive values) or downwards (negative values), while on the Z axis we can recognize movements made by the device forward (negative values) or backwards (positive values).

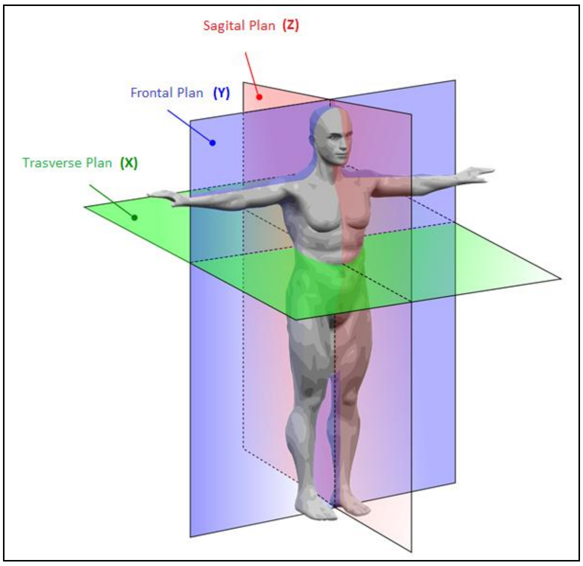



**Fig 2:** Example of axes and plans in relation to the human body

On the X and Z axes the regime value (acceleration value found when the subject is in a stationary position, waiting to start the exercise) is not constant, while on the Y axis is approximately about 9,789 m/s2: gravity acceleration. These non-constant regression values on the X and Z axes may be due to a movement of the device during movement, or to a different inclination of the subject after movement, so we have the influence of 1 g (gravitational force, g = 9,789 m / s2) which is redistributed on the 3 axes in a different way. The technical specifications of the K-Track: (figure 1) are as follows: Accelerometer 200Hz, Magnetometer 200Hz, Weight 25g, Dimensions: 70x20x7 mm, Battery 14h. The test was performed on a youth amateur football team consisting in 18 subjects (Age 11.5 ± 1, Height 1.51 cm ± 10.5, Weight 48 Kg ± 8.3). During the season all subjects performed the same workouts and the same motor skills exercise proposed from the staff. A first "beta" test, was used to make the subjects familiarized with the test, it's was performed 2 weeks before the PRE-TEST.

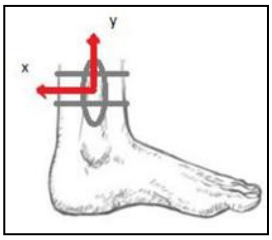



**Fig 3:** K-Track on the Ankle

Before performing the test as a protocol, some device placements have been checked; first on the ankle (Figure 4) which was in contact with the ground (during the Stork Test) and then on the trunk (Figure 5), position which provided more significant data.

**Fig 4:** K-Track on the waist, on the level of iliac ridges

Stork Test Protocol: (30 'standing + 20' test)

The steps of the protocol are:

**1) Sensor Positioning:** the bandwidth must be placed on the waist with the K-track inserted laterally at the level of the last lumbar vertebrae [8].

**2) Sensor On:** From this time the test is switched on and the student has to keep the static position for 30 seconds (hands on the iliac ridges, looking forward, both feet in a comfortable natural position).

After 30 seconds on static position, the subject have to lift a leg (all subjects were left free to choose which leg) and hold the Stork position for 20 seconds. At the end of the 20-second phase, the subject will naturally come back to the standing position, with 2 feet on the ground.

- 30 seconds static: are useful because, due to the natural bending of the back and, possibly, of a non-perfect position of the sensor, the 3 axes of the accelerometer may not be perfectly aligned with the antero-posterior, mid-lateral and vertical axis of the body. Measuring static accelerations is possible to detect an average value of deviation from the ideal situation.

**Fig 5:** Position of subjects during 30 second static phase

- 20 seconds of Stork Test: this is the test phase that give us data on the motor control and equilibrium of the subjects, during this phase the following possibility may occur:
- the subject takes a hand out of the iliac ridges or both;
- he moves his foot to the ground from the initial footprint, making small hops;
- moves the foot in contact with the inner face of the knee;
- tilts with the bust either forward and behind or laterally;
- falls

**3) Sensor Off:** after the end of the 20 seconds the test is completed and the device is turned off.

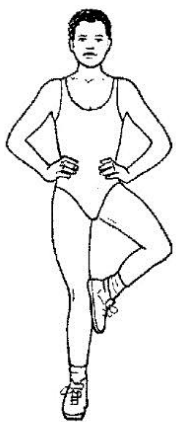


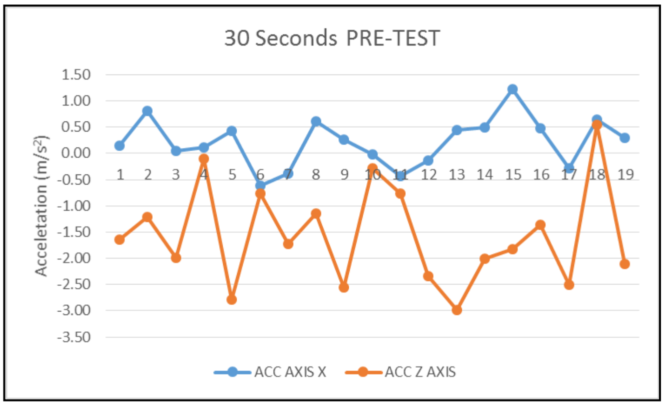
**Fig 6:** Position of subjects during 20 seconds Stork Test

**Used Applications**

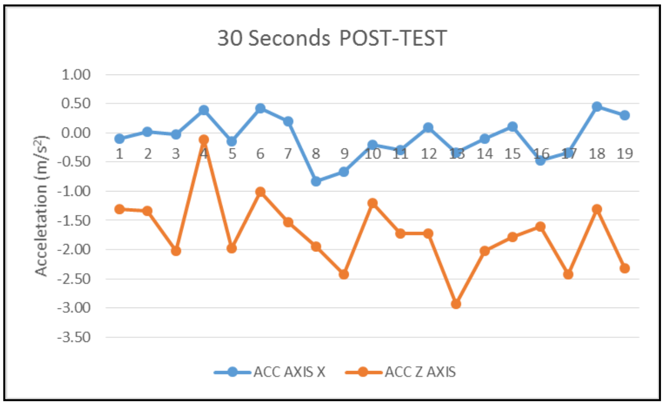
Each subject chose the foot to keep on the on the ground during Stork Test, the one they supposed to have greater stability (14 have chosen the left foot and 4 the right one). The tests was submitted to the subjects in two times: the PRE-Test was in May, and the POST-Test in September. It was also decided to propose the test without the use of the shoes in such a way as to provide an individuality of the various assessments, according to the type of shoes worn there could be compensations that could alter the result of the tests (Schmidt & Lee, 2012). For each test session and for each subject, three trials were asked to perform with two-minutes intervals (one trial between the two and the other students were in sitting position). Of the three tests, the best test was used. To facilitate the study and to give more support to the data provided by K-Track, a video camera (Mini DV 4X Zoom Sportsman Camcorder Digital Video HD 12mp) was used to record each test. Shooting was helpful in analyzing events, and at the same time highlighting any anomalies.

**Data Analysis**

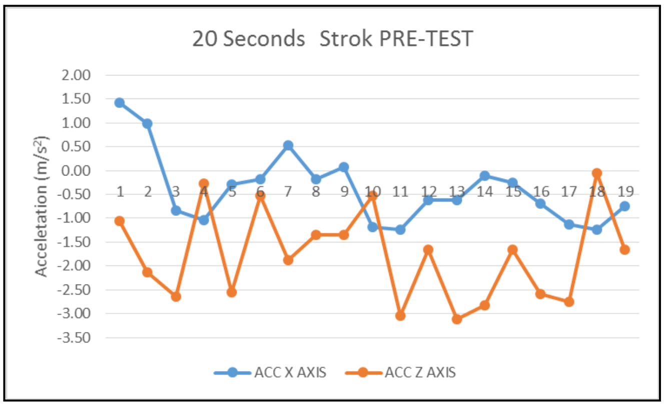
The data provided by the device was processed through the software Matlab (MathWorks, Natick, Massachusetts, United States) to filter relative errors and percentages, afterwards with the data obtained, the tests of each subjects were analyzed, averaging the values acquired at different moments of the test ( 50/30/20 seconds respectively static and dynamic equilibrium). As we will see in the specific analysis, only the acceleration (m/s2) on the "X" and "Z" axes will be reported, while the one on the "Y" axis will be omitted because the subjects haven't performed jumps. In addition to acceleration data, K-Track has also provided angular movements (gyroscopes) that were not taken into account in this study, as it's still being developed and as a result the data provided is approximate and not contextualized pending its validation. With the data we acquired, we developed a graphical analysis for each test and for each subject, called PRE (test performed in May 2016) and POST (test performed in September 2016), to observe each motor's control through the oscillations produced [9]. The graphs below (graphs 1, 2, 3, and 4) show the accelerations "X" and "Z" indicating the movements recorded on their reference axes, so the "X" axis is for the displacements of the body to the left and right (frontal plane), while the axis "Z" for the Forward and Back (sagittal plane). Graphs 1, 2 shows the trending of acceleration on X e Z axis from the 30 seconds standing phase, is easy to understand that; the subjects with more motor control obtain values near 0 in both. During PRE-Test rilevetion 5 subjects obtain a good trending between X and Z axis, instead during the POST-Test only 1. Graph 3, 4 shows the trending of acceleration on X e Z axis from the 20 seconds Stork Test, as could be deducted no subjects obtain values near the 0.



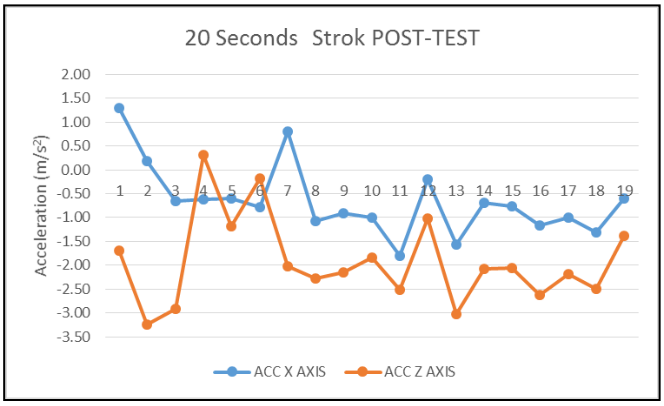

**Graph 1:** Trending of Acceleration on X and Z axis from 30 seconds Standing PRE-TEST




**Graph 2:** Trending of Acceleration on X and Z axis from 30 seconds Standing POST-TEST




**Graph 3:** Trending of Acceleration on X and Z axis from 20 seconds Strok PRE-TEST




**Graph 4:** Trending of Acceleration on X and Z axis from 20 seconds Strok POST-TEST

## Discussion

The results of this work have, first of all, and of course, obviously shown inequality of performance among the subjects. Table 1, 2 shows the average value recorder during PRE and POST 30 seconds static phase on X and Z axis, green indicate the better value and red the worst. It's the same for Table 3, 4 that shows value from PRE and POST Stork Test on X and Z axis. Obviously more the value is close to zero better is the motor control and then stability. About 30 second static phase evaluated on X axis we can see 13 subjects on 19 obtained better value during POST-Test (Table 1), instead on Z axis only 9 subjescts obtain better value in POST-Test. Talking about the 20 second Strok test phase, on X and Z axis 8 subjesct obtain better value then PRE-Test. On average the value obtained from Post rilevation during 30 seconds static phase on X axis was better - 0,08 ± 0,36 (0,22 ± 0,47 Post) instead in Z Post rilevation we recorded a decrease - 1,72 ± 0,63 $m/s^2$ (-1,55 ± 0,96 $m/s^2$ PRE). The average of 20 seconds Strok Test on X axis obtain a decrase on stability between the PRE - 0,39 ± 0,74 and POST - 0,66 ± 0,75 $m/s^2$, the same happened on Z axis PRE - 1,77 ± 0,97 $m/s^2$ and POST – 1,93 ± 0,92 $m/s^2$. As we can see, the data of acceleration Z axis is higher than X, this because the hip joint have physiologically on sagittal plan a higher range of motion then the frontal plan.

**Table 1 e 2:** Data of Acceleration of X and Z axis from PRE-POST 30 seconds Standing Phase

| 30 Seconds Static Phase | | |
|---|---|---|
| Subject | PRE X (m/s^2) | POST X (m/s^2) |
| 1 | 0,14 | -0,10 |
| 2 | 0,82 | 0,03 |
| 3 | 0,05 | -0,03 |
| 4 | 0,11 | 0,39 |
| 5 | 0,43 | -0,14 |
| 6 | -0,62 | 0,43 |
| 7 | -0,39 | 0,20 |
| 8 | 0,61 | -0,82 |
| 9 | 0,26 | -0,66 |
| 10 | -0,01 | -0,20 |
| 11 | -0,43 | -0,29 |
| 12 | -0,14 | 0,10 |
| 13 | 0,44 | -0,34 |
| 14 | 0,49 | -0,10 |
| 15 | 1,23 | 0,11 |
| 16 | 0,47 | -0,47 |
| 17 | -0,29 | -0,33 |
| 18 | 0,64 | 0,45 |
| 19 | 0,30 | 0,31 |
| Average | 0,22 | -0,08 |
| SD | 0,47 | 0,36 |

| 30 Seconds Static Phase | | |
|---|---|---|
| Subject | PRE Z (m/s^2) | POST Z (m/s^2) |
| 1 | -1,64 | -1,30 |
| 2 | -1,22 | -1,33 |
| 3 | -1,99 | -2,02 |
| 4 | -0,09 | -0,11 |
| 5 | -2,79 | -1,98 |
| 6 | -0,76 | -1,01 |
| 7 | -1,73 | -1,53 |
| 8 | -1,14 | -1,95 |
| 9 | -2,55 | -2,42 |
| 10 | -0,28 | -1,20 |
| 11 | -0,77 | -1,73 |
| 12 | -2,33 | -1,72 |
| 13 | -2,99 | -2,93 |
| 14 | -2,01 | -2,03 |
| 15 | -1,82 | -1,79 |
| 16 | -1,36 | -1,60 |
| 17 | -2,50 | -2,43 |
| 18 | 0,55 | -1,30 |
| 19 | -2,10 | -2,32 |
| Average | -1,55 | -1,72 |
| SD | 0,96 | 0,63 |

**Table 3 e 4:** Data of Acceleration of X and Z axis from PRE-POST 20 seconds Strok Phase

| 20 Seconds Strok Test | | |
|---|---|---|
| Subject | PRE X (m/s^2) | POST X (m/s^2) |
| 1 | 1,42 | 1,29 |
| 2 | 0,98 | 0,19 |
| 3 | -0,84 | -0,66 |
| 4 | -1,05 | -0,62 |
| 5 | -0,29 | -0,60 |
| 6 | -0,19 | -0,78 |
| 7 | 0,53 | 0,81 |
| 8 | -0,18 | -1,08 |
| 9 | 0,07 | -0,91 |
| 10 | -1,19 | -0,99 |
| 11 | -1,23 | -1,80 |
| 12 | -0,61 | -0,19 |
| 13 | -0,62 | -1,56 |
| 14 | -0,11 | -0,70 |
| 15 | -0,25 | -0,77 |
| 16 | -0,68 | -1,16 |
| 17 | -1,13 | -1,01 |
| 18 | -1,24 | -1,31 |
| 19 | -0,75 | -0,60 |
| Average | -0,39 | -0,66 |
| SD | 0,74 | 0,75 |

| 20 Seconds Strok Test | | |
|---|---|---|
| Subject | PRE Z (m/s^2) | POST Z (m/s^2) |
| 1 | -1,05 | -1,70 |
| 2 | -2,13 | -3,24 |
| 3 | -2,64 | -2,91 |
| 4 | -0,28 | 0,31 |
| 5 | -2,55 | -1,19 |
| 6 | -0,52 | -0,18 |
| 7 | -1,88 | -2,02 |
| 8 | -1,34 | -2,28 |
| 9 | -1,36 | -2,15 |
| 10 | -0,53 | -1,85 |
| 11 | -3,03 | -2,52 |
| 12 | -1,66 | -1,03 |
| 13 | -3,12 | -3,02 |
| 14 | -2,83 | -2,07 |
| 15 | -1,66 | -2,06 |
| 16 | -2,59 | -2,63 |
| 17 | -2,76 | -2,19 |
| 18 | -0,05 | -2,50 |
| 19 | -1,66 | -1,39 |
| Average | -1,77 | -1,93 |
| SD | 0,97 | 0,92 |

## Conclusions

This study tried to overview the static and dynamic equilibrium and motor control using the stork test helped with K-Track (K-Sport Universal, Italy) a high precision Inertial Measurement Unit (IMU). Trying to analyses the development of pre-adolescent equilibrium on a under 13 amateur football team (Italian) composed of 19 subjects (Age 11.5 ± 1, Height 1.51 cm ± 10.5, Weight 48 Kg ± 8.3) with a PRE-POST protocol. This study was possible thanks to the Advanced Research Group of the School of Sport and Sport Sciences at Carlo Bo di Urbino University, Italy and K-Sport Universal (ITA). The outcomes of this study were:

- On X axis we detected an improvement on the 30 seconds static phase but a decreasing on the equilibrium during the 20 seconds stork test, that means the average acceleration on X axis was higher in the POST-TEST.
- On Z axis we detected a regression of equilibrium in both phase (30 seconds static and 20 seconds stork test)
- The value of acceleration on X axis as in average lower then the acceleration detected on Z axis, this can be explained with the physiological structure of the hip joint (where the IMU was posizionated), because the hip have higher range of motion on the sagittal plan
- In average all the subject obtain a decrease of equilibrium capacity during the test period, that can be explained with the weight and statural growth, that obviously adversely influence the motor control and equilibrium capacity.

Although the results are significant and interesting, is possible to improve outcome values by expanding the workgroup and application areas (category), it might be fascinating to conduct the Stork test periodically to see the trend during a football season. Another variable could be to propose analysis by wearing shoes. Ours therefore remains a preliminary study, which would be a starting point for the development of further outcomes. Particularly interesting and important, in our view, would be the application of such hardware in the evaluation of all ages, in this way will be possible to establish a golden standard of motor control and equilibrium capacity.

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