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Original Article

Dynamic inertial analysis of the technical boxing gesture of Jab

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Abstract

The purpose of this study is to analyze the inertial dynamics of the Jab technical gesture in boxing. The target is to test and establish with the precision of the latest generation inertial technology the real physical parameters of the mechanical components of the technical gesture subjected to analysis to use, in the event of an expected congruence, the parameters obtained as key elements in the project of sports training investigated for performative purposes, given that the literature on this subject is scarce and sometimes with data obtained using non-state-of-the-art equipment and therefore not reliable. Five boxers (n = 5) took part in this research, considered sufficient for an exploratory study, respectively two female (n = 2), (18.5 ± 6.4 years, weight 63.7 ± 0.4 kg, height 169 ± 1.4 cm; arm length 69.5 ± 2.1 cm) and three male (n = 3), (23.0 ± 3.5 years, weight 80.0 ± 7.0 kg, height 184.3 ± 7.1 cm; arm length 79.7 ± 2.5 cm). These athletes were from different levels of experience, also to obtain specific threshold data in the various stadiums, however, all participating in national level competitions (elitè level). From the dataset, it's possible to appreciate a different average acceleration value in the Jab execution phase between 8.65 m/s² (woman) and 13.85 m/s² (man) of the stroke, statistically significant ($p < 0.05$), even in the small sample. The same situation is true for the torsion phase of the trunk between the best performing male boxer (boxer 1) and the best female boxer (boxer 5) respectively 0.733 vs 0.338 g² ($p < 0.05$). This allows us to understand how gender and category differences are a key element in relation to the training planning of the discipline and that often turn out to be quite generic and that doesn't take into account accurately and weighed the differences and what are the values to be respected in the specific training workload and also in the performance level of the exercises necessary to achieve those physiological conditions and techniques useful for performance improvement. The differences in this sample were also evident between individuals of the same gender and level.

Key-Words: boxing, IMU, performance analysis, movements evaluation.

Introduction

The goal of this work is the analysis of a basic technical gesture in boxing, describing in a more descriptive way the actual reality of the physical qualities of the same to establish more correct parameters to be used in the construction and adequacy on training the investigated discipline in function to performance. It's noted that in literature there aren't numerous studies on the analysis of the technical gesture of boxing; however, among the most recent is the study carried out by Kimm D. et al. (2015) and it showed that the overall speed of the blows improves with experience, regardless of age and gender. In this regard, specific research on the effects of aging suggests that maximum performance is achieved between the ages of 20 and 30 and that the decline in performance can be attributed to physiological aging or to a decrease in the extent and intensity of training. The study also highlighted that the Jab blow is faster than the cross blow. The second study, conducted by Chadli S. et al. (2014), evaluates the forces of the blows in relation to the frequency of impact and the reaction time; these surveys make it possible to provide information on the intrinsic performance of athletes [2]. The maximum strength of the boxer, his acceleration, the contact time, the reaction time of the punch on the target, the frequency of the punches in a series of attacks. A further study, carried out by Buśko K. et al. (2014), focused on two methods intended to measure specific elements: the strength of the fist, the thrust, and the reaction time of athletes. The evaluation systems have been designed to measure and analyze the mechanical characteristics of the punches and blows delivered by the upper and lower limbs on a punching bag. The first method of evaluation used strain gauges, while the second used accelerometer technology [3]. In 2013, a new BTS-4AP-2K diagnostic system was designed. The key element of the aforementioned is a dynamometric punching bag equipped with two triaxial accelerometers mounted on the side surfaces, inside the bag, which, like other accelerometers inserted

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directly inside basketballs and volleyballs, such as those inserted inside of competitive sports shoes have never passed the scrutiny of serious reliability of the data obtained. Regarding boxing blows, it is correct to define a jab as the blow carried with the forward limb and cross the blow carried with the rear limb. The task of the jab is usually to disturb, keep at a distance, wear out the opponent and open the way to the most powerful blow the cross [7,8].

Jab Executive Technique: For a simplification of the exposure, we take as a reference a fighter in the most common guard position or with the left side advanced in the direction of the opponent:
1. the knee of the rear leg is extended, triggering the rotation movement of the pelvis;
2. at the same time, a rotation of the trunk also takes place, the mass of which will impart power to the blow;
3. the upper limb extends and simultaneously performs a partial intra-rotation until the fist is parallel to the ground;
4. the shoulder is raised to cover the chin, to protect it from a possible counterattack by the opponent.

The cross blow compared to the jab, have a greater amplitude of the rotary movement, this determinate an higher acceleration, which translates into an increase in the power of the blow. The reason why the cross is more powerful than the jab is due to the greater distance traveled by the punch, which allows it to accumulate more kinetic energy. The study we propose, based on measurements made with the latest generation three-D inertial sensors, aims to analyze the fundamental technical gestures of boxing, mechanically breaking down the movement performed, to evaluate the different physical parameters, thus guaranteeing the construction of the training based on the real demands of the performance.

Means and methods

The study group was designed in 5 boxers (Tab.1) and divided in 3 men and 2 women, only the Boxer 1 is an elite/professional athlete.

	AGE	GENDER	WEIGHT	HEIGHT	ARM L.	GUARD
BOXER 1	25	M	75 KG	178 CM	77 CM	LEFT
BOXER 2	25	M	77 KG	183 CM	80 CM	RIGHT
BOXER 3	19	M	88 KG	192 CM	82 CM	RIGHT
BOXER 4	23	F	64 KG	168 CM	68CM	RIGHT
BOXER 5	14	F	63.5 KG	170 CM	71 CM	LEFT

Tab.1. Anthropometric characteristics of boxers

The investigated gesture was broken down into three phases in succession and defined: Preparation phase; Execution phase and Retraction phase. Two inertial devices were used for each athlete, one in the harness between the shoulder blades and one on the wrist, the latter using a specific and very adherent bandage so that the instrument could not move, as for the fitting of the bib, so as not to distort the findings [4,5], to be able to check all the movements performed by boxers during training (Table 1). After the biomechanical analysis of the blow, we evaluated the respective physical elements that characterize it. The K-TRACK (K-Sport World, Ita) is the latest generation triaxial IMU sensor (Fig. 1), which has a recording capacity up to 3200 Hz, which has been set to 100Hz on each axis for acceleration measurement (acc. x, y, z), angular accelerations (gyro x, y, z), and the trajectories of hits with the magnetometer (mag. x, y, z) [6]. A significance level of $p < 0.05$ was set. All data were accompanied by mean and standard deviation. The elements taken into consideration through the IMU surveys are, therefore: Speed, Acceleration, Deceleration and Symmetry Index of blows.

Fig. 1. *K-TRACK (K-Sport Universal, Ita)*

The protocol was carried out as follows for all athletes:
- General and specific warm-up (joint mobility, gaits, rope and 20 repetitions of jab blow)
- The boxer in a position in front of the punching bag in an attitude of the guard;
- Repetition of a series of 15 strokes;
- Executive protocol: 10 seconds (Preparation phase) - 5 seconds (Execution phase) - (Arm Flexion-Retraction phase);

The pause between phases, are included in order to better visualize the difference repetitions. Example of phases are showed in following figure, starting from preparation phase, execution and retraction phase (Fig.2).

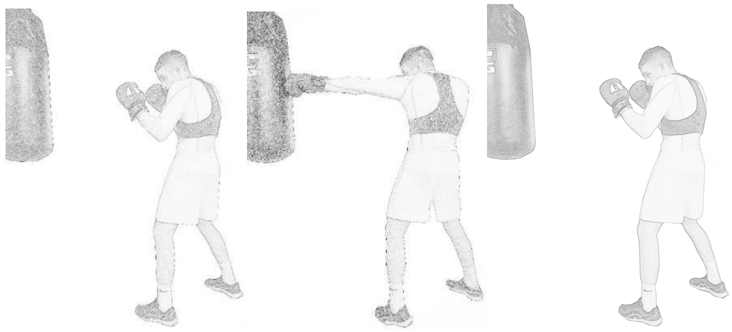


Fig.2 Example of phases of Job Blow

Results

The study shows that there is a different average value in the Jab execution phase between 8.65 m/s² (woman) and 13.85 m/s² (man) of statistically significant mean acceleration of the stroke ($p < 0.05$), even in the small sample. This allows us to understand how gender and category differences are a key element in relation to the design of the training of the discipline and that often turn out to be quite generic and that do not take into account accurately the differences and what are the values to be respected in the workload during training of athletes and also of the performance level of the exercises necessary to achieve those physiological conditions and techniques useful for improvement. At the same time, there is a statistically significant difference between boxer 1 of the national elite level and the boxer 2 and 3, all male as regards the values of the execution phase of the Jab and torsion of the trunk ($p < 0.05$) and that is the salient phases for the best performance of the blow.

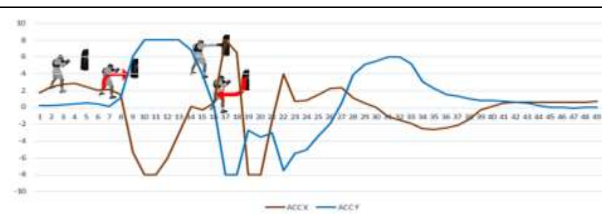
	Average Job Blow Value (m/s2)	**Average Trunk Torsion (rad/min)**
Boxer 1	13,85	732
Boxer 2	11,1	580
Boxer 3	12,98	580
Boxer 4	9,86	272
Boxer 5	8,65	337

Tab.2. The phase of execution of the jab and torsion of the trunk ($p < 0.05$)

Similarly, boxers 4 and 5, of the female gender, have a statistically significant difference in the torsion parameters of the trunk (272 vs 337 rad/min, $p < 0.05$) (Tab. 2). From these analyzes, using the inertial system, it is clear how it is necessary to correctly program the training load according to the competition performance in the ring. From our research, we can deduce how extremely important it is to pay attention to the technical and physical level of boxers.

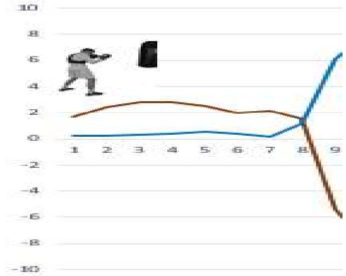
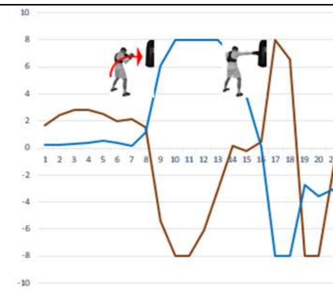
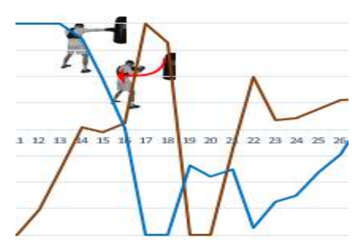
Discussion

Following the biomechanics description of the faster blow detected for each athlete. The first analysis was carried out on an elite boxer and the jab left was examined. A device (K-Track) was placed inside the bandage horizontally to the blow arm and a second device inside the bib was placed in the middle of the shoulder blades. In the graph the results of the inertial sensor placed in the bandage on the wrist:

Left Jab Boxer 1	
Phases of the left Jab Boxer 1	

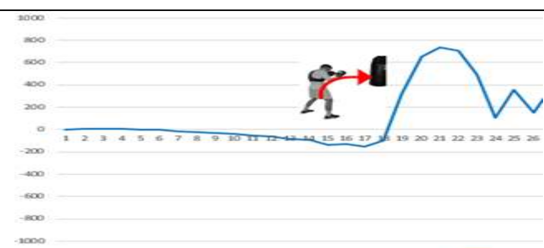
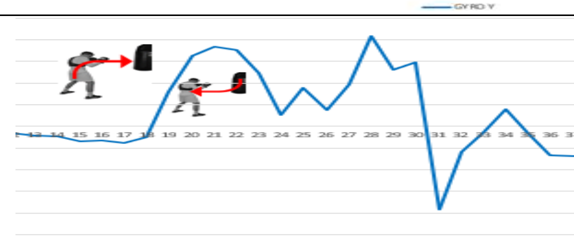
Graph 1. Phases of the Left Jab Boxer 1

This graph represents the acceleration of the Jab left on the X, Y, Z axes whose K-TRACK has been positioned inside the bandage, from which we can go to identify the 3 phases of the biomechanical gesture (Graph 1.). The resultant of the three accelerations on the three planes were then calculated to evaluate the maximum acceleration of the blow at the moment of impact on the bag. By analyzing the accelerations on the X and Y axis, we can identify the three phases of our study (Graph 1.). In this phase, the boxer, based on the laterality of the upper limb, positions himself either with the left leg forward or with the right leg forward; this depends precisely on the dominance between the right and left upper limbs. In this analysis, the boxer has a significant dominance of the right limb, so he positions himself with the left leg slightly ahead of the right. The legs are slightly bent and the movement takes place on the forefoot; the hands are flexed to cover the face with the left limb slightly forward as well as the leg itself (Graph 2).

First Phase: PHASE OF PREPARATION ON THE GUARD	
Second Phase: EXECUTION PHASE	
Third Phase: BENDING PHASE (RETRACTION)	

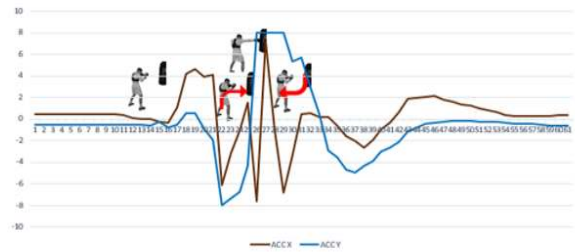
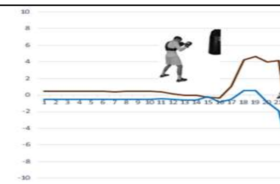
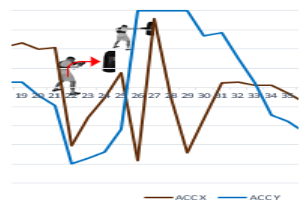
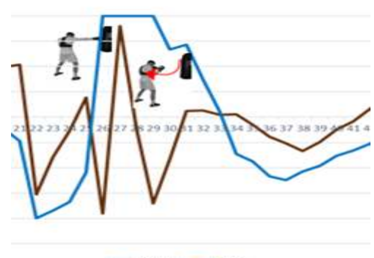
Graph 2. Phases of the Jab of the Boxer 1

In the execution phase, the knee of the rear leg is extended, triggering the rotation movement of the pelvis, at the same time the upper limb extends and simultaneously performs a partial intra-rotation until the fist is parallel to the ground; the shoulder is raised to cover the chin, to protect it from a possible counterattack by the opponent. In this phase, the boxer returns to the initial position or on guard and then makes a subsequent blow. In the graph the results of the K-Track placed in the bib:

Gyroscope: Twisting, stance, guard	
First Phase: TRUNK TORSION PHASE	
Second Phase: RETURN TO THE GUARD	

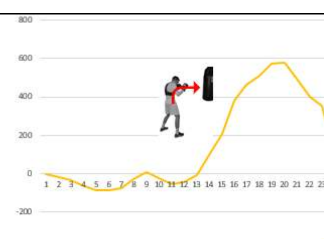
Graph 3. Findings K-Track Gyroscope Boxer 1

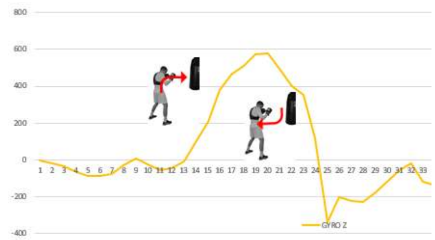
This graph represents the data of the gyroscope, and we can analyze the moment in which we have the torsion of the torso during the strike, the return to the position on guard, and finally the various movements of the boxer after returning to the guard (Graph 3). In this first phase, we have the torsion of the torso which occurs when the boxer begins to perform the blow given by the movement of the rear leg which is extended and which allows, with the rotation of the torso, to impart power to the blow (Graph 3). In the second phase of the gyroscope analysis, we have identified the phase in which the boxer's return to guard occurs and therefore the return of the trunk to the initial position which always occurs on the Y-axis whose value returns close to 0, as we can see from the figure. From this analysis, we can also see the various movements made by the boxer after returning to his guard (Graph 3). In the graph the results of the K-TRACK placed on the wrist:

Right Jab Boxer 2	
The phase of the right Jab Boxer 2	
First phase: PHASE OF PREPARATION ON THE GUARD	
Second Phase: EXECUTION PHASE	
Third phase: BENDING PHASE (RETRACTION)	

Graph 4. Phases of the right Jab Boxer 2

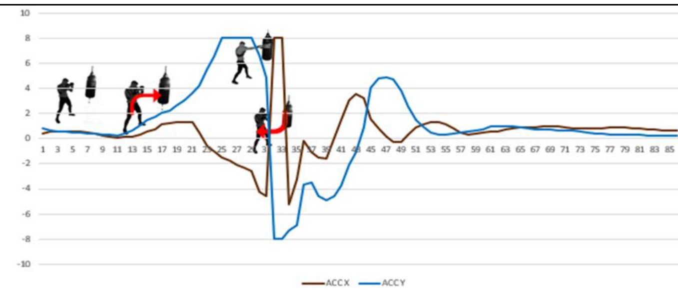
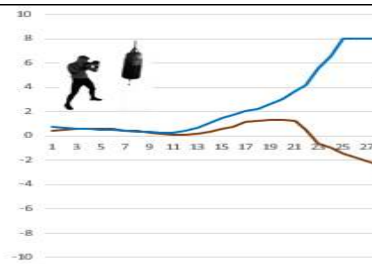
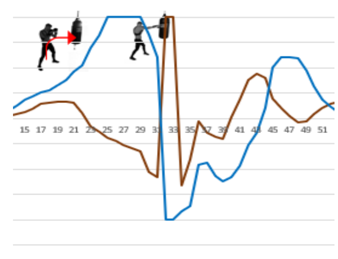
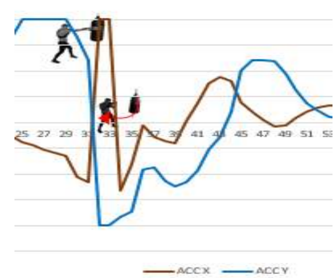
Comparing the execution phase with the Elite boxer, we can observe a longer execution phase (third boxer value = -8 - (Elite boxer) value = -0.122), possibly due to a pre-loading of the blow (Graph 4). In the graph the results of the K-Track placed in the bib:

Gyroscope: Twisting, stance, guard	
First Phase: TRUNK TORSION PHASE	

Second Phase: RETURN TO THE GUARD	

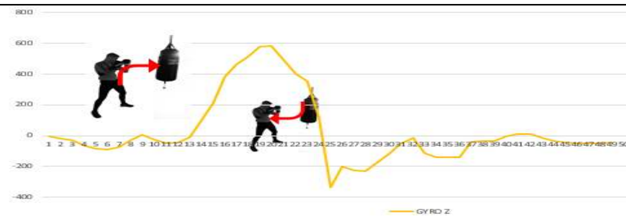
Graph 5. Findings K-Track Gyroscope Boxer 2

In this graph, we can see how the torsion and the blow executed by the second boxer, presents a wider torsion compared to the Elite boxer who has a more linear and shorter curve that we can identify as a technically well-coordinated execution and therefore fast and strong (Graph 5). In the graph the results of the K-Track

Right Jab Boxer 3	
The phase of the right Jab Boxer 3	
First phase: PHASE OF PREPARATION ON THE GUARD	
Second Phase: EXECUTION PHASE	
Third Phase: BENDING PHASE (RETRACTION)	

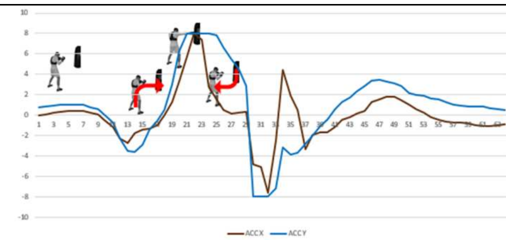
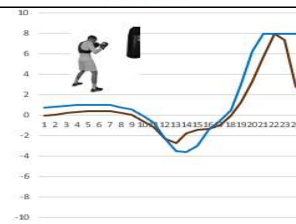
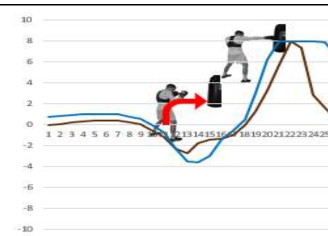
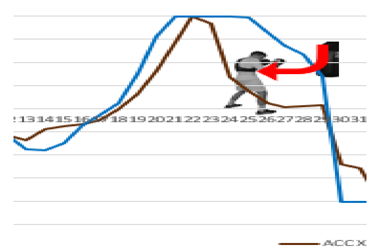
Graph 6. Phases of the right Jab Boxer 3

The analysis of the third boxer is very similar to the execution of the boxer Elite; we can see how the execution of the blow is linear and the difference that can be seen is the impact time which is shorter than the elite boxer, in fact, we can highlight a value of 12.98 m/s² in the third boxer and 13.85 m/s² in the elite boxer and therefore a superior force expressed in the moment of contact with the bag (Graph 6). In the graph the results of the K-Track placed in the bib:

Gyroscope: Twisting, stance, guard	
First Phase: TRUNK TORSION PHASE Second Phase: RETURN TO THE GUARD	

Graph 7. Findings K-Track Gyroscope Boxer 3

To anticipate a gender work, we present two female boxers, respectively aged 23 and 14. In the figure the results of the K-Track placed in the bandage:

Right Jab Boxer Analysis 4	
Phases of the right Jab Boxer 4	
First phase: PHASE OF PREPARATION ON THE GUARD	
Second Phase: EXECUTION PHASE	
Third phase: BENDING (RETRACTION) PHASE	

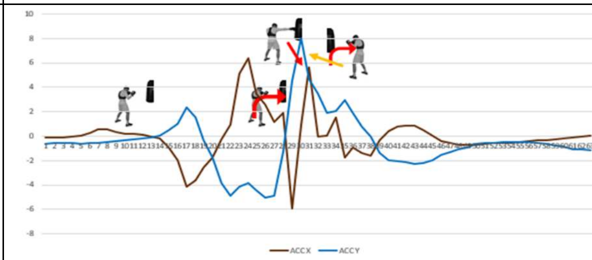
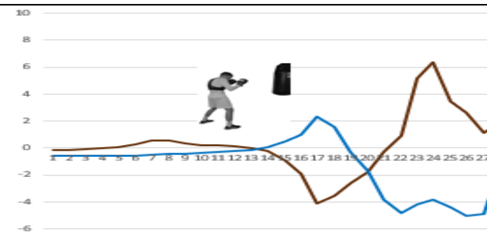
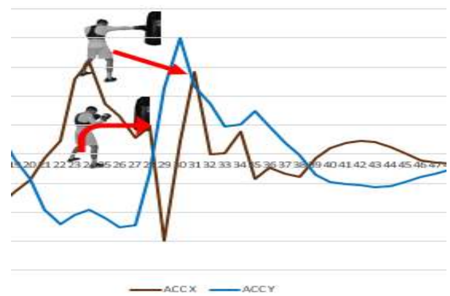
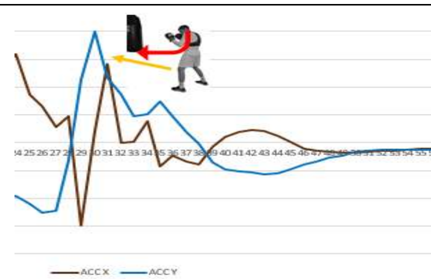
Graph 8. Phases of the right jab Boxer 4

In the blow performed, we can see a precise technique, in which the stroke is linear in the progression of the three phases of the gesture; we have a value of 9.86 m/s² as regards the results of the three accelerations higher than the fifth boxer which is 8.65 m/s² (Graph 8). In the figure the results of the K-Track placed in the bibs:

Gyroscope: Twisting, stance, guard	
First Phase: Trunk TORSION PHASE Second Phase: RETURN TO THE GUARD	

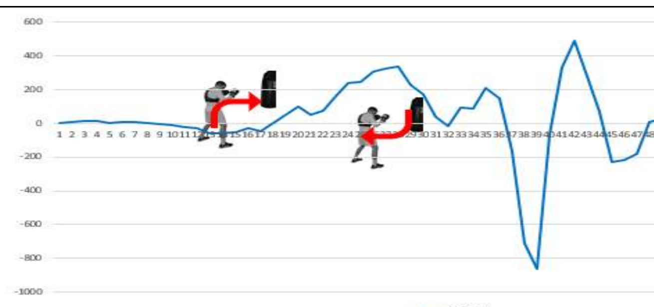
Graph 9. Findings K-Track Gyroscope Boxer 4

In the figure the results of the K-Track placed in the wrist bandage:

Left Jab Boxer Analysis 5	
Phases of the left Jab Boxer 5	
First phase: PHASE OF PREPARATION ON THE GUARD	
Second phase: EXECUTION PHASE	
Third phase: BENDING (RETRACTION) PHASE	

Graph 10. Phases of the left jab Boxer 5

In the figure the results of the K-Track placed in the bibs:

Gyroscope: Twisting, stance, guard	
First Phase: TRUNK TORSION PHASE Second Phase: RETURN TO THE GUARD	

Graph 11. Findings K-Track Gyroscope Boxer 5

Analyzing the data, we can see the differences between one boxer and another. The average execution value of 13.85 m/s² in the elite boxer (Graph 12) is highlighted, this allows us to make a first distinction compared to other boxers by highlighting a fast, strong blow and therefore greater power in contact with the bag. As regards the torsion phase of the trunk, calculated with the K-Track device positioned inside the bib, we can see how the torsion speed of 732,7 rad/min (Graph 13) in the elite boxer is higher than in other boxers, and therefore this component is important in the execution of the blow.

Conclusion

In our study, we were able to analyze the physical elements that make up the jab in boxing, highlighting the average acceleration of the blow and the average acceleration in the torsion phase, obtaining data that differ from each other also due to a different sporting experience, age, and training as well as gender. These athletes were from different levels of experience, also to obtain specific threshold data in the various stadiums, however, all participating in national level competitions (elitè level). From the dataset, it has been possible to appreciate a different average acceleration value in the Jab execution phase between 8.65 m/s^2 (woman) and 13.85 m/s^2 (man) of the stroke, statistically significant ($p < 0.05$), even in the small sample. The same situation is true for the torsion phase of the trunk between the best performing male boxer (boxer 1) and the best female boxer (boxer 5) respectively 0.733 vs 0.338 g^2 ($p < 0.05$). This clarify how gender and category differences are key elements in relation to the training planning of the discipline and that often turn out to be quite generic and that doesn't take into account accurately and weighed the differences and what are the values to be respected in the specific training workload and also in the performance level of the exercises necessary to achieve those physiological conditions and techniques useful for performance improvement. The differences in this sample were also evident between individuals of the same gender and level. Moreover the data and the differences between individuals that we have collected will allow us in the future to establish ideally adequate working protocols with a larger sample of boxers, to be able to definitively validate the inertial instrument (K-Track), and the different parameters obtained in this study, for this discipline at the aim to improve the technical gesture and the performance of the boxers. This research even allowed us to better understand the postural and body positioning aspects of these athletes, who often, due to the discipline practiced, have to face the asymmetries generated by the blow performed, which affect the body structure. The same for female boxers, where there is a significant difference in the execution of the blow, which allows us to better understand the importance of adequate strength work for the upper and lower limbs. Future studies using this technology will be necessary to better optimize the performance of this sport for both men and women.

Author Contributions:

Conceptualization: Izzo R., Materazzo P.
Methodology: Izzo R., Giovannelli M.
Validation: Izzo R., Cejudo A., Hosseini C.
Formal analysis: Giovannelli M., Materazzo P.
Investigation: Materazzo P., Izzo R., Hosseini C.
Data curation: Izzo R., Hosseini C., Giovannelli M.
Statistical analysis: Cejudo A., Izzo R.
Writing, original draft preparation: Izzo R., Materazzo P.
Writing, review, and editing: Izzo R., Cejudo A., Giovannelli

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Citation Index

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