

Examining key components in table tennis performance involves analyzing accelerations in elbow and wrist rotations through a physical assessment of technical gestures utilizing inertial sensors an exploratory approach

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Abstract

This study aimed to quantify and analyze the acceleration and rotation of the upper limb during three fundamental techniques in table tennis. The chosen instrument is the inertial sensor K-TRACK, (K-Sport Montelabbate, Italy) equipped with 3D sensors capable of reading up to 4000 Hz (operating at 200 Hz). The experimental group for this research comprised athletes from the National Table Tennis Team of San Marino. The experimentation involved each of the six athletes executing 100 forehand topspin shots, 100 backhand topspin, and 100 serves, resulting in a total analysis of 1800 shots. From an extensive review carried out, we can state that it is the first time that the specific tools have been used in table tennis and that the quantity and quality of the data collected have approved a significant impact and revision of the methodological issues used up to now in the training structure of table tennis. The specific elements on which we have concentrated are those that have been deemed decisive for better establishing the working times of the training elements such as the acceleration of elbow and wrist rotations, of the dominant limb, for each of the fundamentals analyzed. From the surveys of forehand topspin, for example, it has been established that the upper limb almost exclusively plays a directional role and a little propulsive one, while the lower limbs and the back impart most of the acceleration to the ball and if up to date this concept could have been presupposed now this fact is incontrovertible and above all quantifiable. The difficult step of abandoning, at least in a constructive phase of training programming, experientiality, and personal idea, in favor of an objective and scientific analysis, is increasingly evident, numbers instead of opinions, as in part already happens at the today high level. However, the experience will return to play its decision-making role for the final choice and in the tactical-strategic setting as the predominant element in game management.

Key words: Table Tennis, IMU, Elbow/Wrist acceleration, new approach.

Introduction

This work wants to test in a new way with inertial technologies (of the latest generation) and in ways of using the same originals, enriching the investigated discipline by filling a lack that in table tennis still appears evident, in order to obtain objective parameters useful for the construction of a more scientific and adequate training plan, as well as less linked to the sole, albeit important, the experience of the technical staff by crossing the real needs of the sport in question and of the individuals who practice it. After careful discussion within the research group, the academic staff (ARGs, Advanced Research Group in Sport) and the engineers of the company involved (K-Sport, Ita) it was decided to position the K-track tool (an inertial sensor-IMU of the latest generation) on the athletes' wrists, believing that it was the position that would have returned a number of more coherent data with respect to the gestures investigated and not in the typical interscapular position, in order, therefore, to better evaluate the acceleration of the upper dominant limb in correlation with the rotation of the wrist and elbow, even if the instrument, having the size of a USB stick, could be easily positioned in different parts of the body.

State of art

Many studies have been carried out on table tennis, all over the world, and the state of the art is large and varied. The writings that will be reported are the most recent and significant in relation to the research, from 2010 to the most recent with some historical regression to better explore some concepts. As stated in the research

carried out in Japan by Hayashi et al., 2017, the element of greatest characterization is undoubtedly the speed that the ball can reach, obviously correlated with the length of the table available (137 cm in length and 152 cm in width) and with the diameter of the ball 40 mm for 2.7 grams, with effects that are always variable in direction and intensity. In a normal game exchange, the speed of the ball varies from 10 to 20 meters/second, about 36 km/h but the most violent attacks can reach 200km/h.

The speed is very high and therefore the athletes have to plan their game and therefore the position of the body, the type of shot, and the tactics, also analyzing the indications that are provided to them by the execution of the shot that the opponent is executing. It is therefore clear that a player will be able to reach a level that is as high as his ability to analyze and consequently solve the game problems that arise from time to time will be better. It should also be added that there is a necessary time for the optical signal transmitted to the brain to be transformed into movement, this reaction time is on average 200 thousandths of a second (Boyer et al., 2013). Research conducted by Baca et al. (2010) states that in order to hit the ball in time, the player must anticipate, and the basis of this anticipation is the most exact possible perception of the speed, spin, and direction of the ball, as well as a sense of the speed at which one's racket will be placed in use. In addition to anticipation, the prediction of the opponent's movement is also necessary, this prediction is triggered with the start of the opponent's movement, so it can be said that there is an anticipated reaction. In order to achieve good results, it is therefore essential to have a long experience and training, as varied as possible. Another important feature that has been highlighted by Baca et al., 2010, is the kinesthetic perception that allows the athlete to differentiate and dose the muscular effort and above all to perform the technical gesture in a spatial distance that respects particularly precise angles without that direct visual check is involved (Munivrana et al., 2015). Billi (1984), writes in his book that by now in all sports it is now established that the degree of development of the basic and specific motor qualities is the essential basis of technical-tactical training. Even more important is the specific manifestation of physical qualities which, very often, manifest themselves not alone but in an interdependent manner with respect to others. In table tennis, it has been shown that the determining quality is "dexterity" coupled with speed.

The latter is important not so much as movement speed as reaction and execution speed, even if dexterity and speed are mostly innate qualities it has been scientifically proven that systematic training can reduce the response time to a signal of approximately 25% luminous and to an audible signal in a variable measure between 25 and 30% (Moura et al., 2018). As far as the speed of execution is concerned, it has been demonstrated by the research of Strino and Flavia in "Tennis table tennis theories of training", 1987, that an improvement in motor coordination can lead to a significant increase in frequency, undoubtedly the rhythmic sense also plays a role important for both reaction speed and execution speed. Furthermore, the psychological element gives the possibility of emerging only to those who know how to maintain effective self-control, in fact, it is no coincidence that table tennis has a greater developed in Asian countries, where the most practiced disciplines are those that use motor skills, sport, in close connection with philosophy (Malagoli et al., 2014). Table tennis is a metabolically intermittent sport characterized by short game exchanges and short breaks. In table tennis we can define the most important element as the speed of execution of the movements, required by the dynamics of the game and by the speed of execution of the gestures and given the brevity of the technical gestures both in terms of time and space, they give the idea of the fundamental attention to be given to accelerations which are the flywheel for achieving the best executive speeds in the very shortest time. The significant shifts in table tennis are 1-2 m (1-2 steps), with a "chasse" step at maximum speed for a short distance, or when the player stands away from the table with a shift of 2-3 steps. It is a situation sport and you have to deal with complex motor situations and choice reactions. A study conducted at Cheangchi University in Taiwan (Tamaki et al., 2017) through the metabolimeter measured energy expenditure and cardiovascular response during training and in simulated matches. Since 2016 the diameter of the ball has officially changed internationally, from 38mm to 40mm.

The larger balls can be given a speed (13% less) and a smaller effect (23% less), in this way the rallies of the game are increased and also its spectacularity. This change has led to an increase in energy expenditure during the match, while it has not brought about changes in the skills required in the sport such as tactics, mentality, and physical strength of the athletes. To carry out this evaluation they used two "Cortex Metalyzer 2B" and the goal was to identify what the energy expenditure index was. Maximum oxygen capacity VO_{2max} is represented by the efficiency of the body to use oxygen and helps us understand how our athlete recovers. The recorded average of the 60 subjects taken into consideration by the cited study was, during training 29.8 ± 7.2 ml*kg⁻¹*min⁻¹, and during simulated competition 36.8 ± 13.2 ml*kg⁻¹*min⁻¹ (12). In this study, anthropometric measurements were initially carried out two days before the start of training, after which the athletes were divided into two equivalent groups in accordance with the "Table Tennis Battery Test". The two "basket" training protocols that were prepared differed only in the duration of the exercise (Group A: 15 sec.; Group B: 30 sec.) while the percentage of ball throws per minute was the same in the two groups, about 80 balls per minute. During the research the athletes did not perform further training, the study was carried out for 1 month and a half (6 weeks) with 3 trainings per week. The precise indications of the heart rate of the athletes were detected by performing the forehand and backhand techniques and the union of forehand and backhand using the chassè step. The "Polar Team System" was used to record the heartbeat, and the "Polar Precision Performance 3.0 Software"

with 2 HD digital cameras was used for the analysis of the data collected. Heart rate was recorded pre- and post-workout for 6 weeks. Data were checked using "Kolmogorov-Smirnov analysis" and all data were processed by IBM-SPSS 19.0 Windows software. The measured heart rate values ranged from 111 to 210 b*min in group A (15sec.) and from 110 to 192 b*min for the athletes in group B (30sec.). The highest heart rate values were detected during the combined exercise of forehand and backhand with step chassè, in both groups and as the weeks progressed, an increase in heart rate was detected during the exercises. In the evaluation of racket sports, it is common to analyze the type of shot, the number of shots performed in a rally or in the unit of time, and the outcome of the rally. Shots can be divided into 7 categories:

- "Push", in which you respond with a dribble with a backward rotation of the ball;
- "Flick", is an attacking shot used when the ball bounces close to the net;
- "Topspin", is an attacking stroke imparting a forward rotation to the ball;
- "Block", is a defensive stroke performed in response to an opponent's topspin,
- "Top-counter-top", is a counter-attack stroke following an opponent's topspin;
- "Cut", is a defensive stroke used by players who are far from the table;
- "Smash", is an attack hit characterized by the absence of rotation that is imprinted on the ball;

The shots most associated with winning the point are topspin and top-counter-top forehand, but the most widely used shot is the forehand serve. Strictly connected to the action of the strike is the step performed previously, in fact, a close correlation has been found between the type of step and the type of strike that can be performed (Zhang, et al., 2013). The classification of steps can be summarized into 6 different categories:

- "One step", is a step forward (with one foot only, the other remains stationary) to catch a drop ball;
- "Chassè", is a lateral step by starting the movement with the foot opposite to the direction in which you want to go;
- "Slide", is a lateral step but the movement starts with the same foot you want to move towards;
- "Pivot", is a step like a slide or chassè but a backward movement is associated with it and this allows you to rotate around the vertical axis;
- "Crossed step", is a lateral step in which the foot opposite to the direction you want to go first slides, and then the other foot crosses them;
- "No pass", ie when the player hits the ball without taking any steps.

The most used steps during won points are pivot, crossover, and chassè, but the most used step is the "one step" and one of the most used shots in table tennis is the forehand topspin (Malagoli et al., 2010). Topspin is an open kinematic chain movement with the aim of accelerating the distal segment as much as possible and consequently the racket. When two neighboring body segments rotate in the same direction, mechanical energy can be transferred from one segment to the other due to the tension of the muscles crossing the joint formed by the two segments. In table tennis, during forehand topspin, energy can be transferred from the trunk to the upper limb during the forward swing and rotation of the trunk and upper limb. In this study, the importance of the generation of mechanical energy and consequently speed, and its transfer to the dominant limb for forehand topspin was established.

An element that creates the angular acceleration of the movement of the joint is the torsion and internal rotation of the shoulder, which substantially contributes to creating speed during the impact of the racket with the ball. Elbow flexion increases the effectiveness of shoulder internal rotation resulting in higher impact velocity and may also contribute to increased ball spin. It was noted during the study that the advanced-level players, compared to the intermediate-level athletes, the internal rotation of the shoulder and the rotation of the elbow and wrist are greater. The rate of energy transferred by internal rotation of the shoulder depends on the angular velocity component of the upper trunk which must be on the same axis as the upper limb; therefore, if they are on the same axis there is a better transfer of energy and therefore it is possible to impress greater speed and force on the elbow, wrist and finally the racket. This can also be very important for planning adequate physical preparation, both to prevent injuries and to increase the force with which the ball is hit (Shiei et al., 2010, Yoichi Iino et al., 2011).

Means and Methods

In this study, we wanted to analyze three fundamental shots in table tennis: forehand topspin, backhand topspin, and serve. Each shot can be broken down into three different phases: initial or preparation, execution or impact with the ball, and final phase. The inertial sensor K-Track (K-Sport, Montelabbate Ita.) was used for our study, and the accelerations that occurred by the upper limb of execution were detected.

The K-TRACK used had the following characteristics, which at the time of research were the most advanced on the market: 1000 gyroscopes, IMU sensor, Sampling frequency 4000Hz, Full-scale accelerometer 16 g and 4000 degrees/sec (Izzo et al, 2019). To carry out the practical protocol of the research, given the experimental nature of the technologies in the sport under investigation, 6 players of the San Marino national table tennis team were selected, aware of the low statistical significance of the sample, which will be expanded at a later time, given the high pertinence with the objective of the research, as it was revealed at the end of the

study. Athletes in different age categories ranged from 15 to 33 years old with at least 6 years of gaming experience, including 4 males and 2 females. Various data such as weight, height, BMI, and arm length were recorded (subsequently reported in the table). Each player performed 100 shots for each fundamental analyzed (forehand topspin, backhand topspin, and service through the use of the "basket" (to draw on the balls to be used for each gesture), therefore a total of 1800 shots were recorded and analyzed for the whole group.

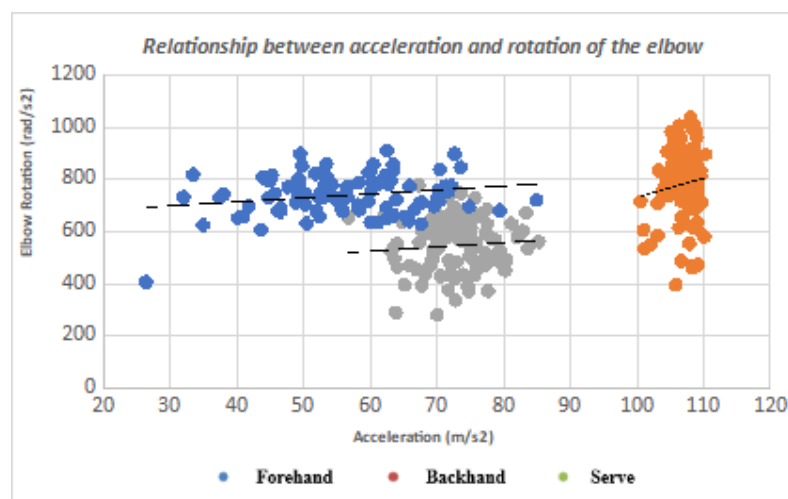
The instrument, as mentioned, was positioned on the wrist thanks to the use of a rather containing cuff having to guarantee total adherence to the arm to avoid altering the collected data. Having the dimensions of a USB flash drive, its use proved to be simple and easily repeatable and did not influence the technical gesture or annoy the athletes. After performing 100 technical gestures for each required type, the subjects performed a complete recovery between the series (Table 1,2). A latency time of 3 seconds was made between one shot and another in order to have a clearer and more precise image of the shot in reading the graphs. The experimentation was carried out in the middle of the week (Wednesday) to have a complete recovery from the competitive activities of the participants carried out during the weekend. Example of the correlation between data recorded from each players are exposed in Graphic 1,2,3.

Table 1; Study Group details

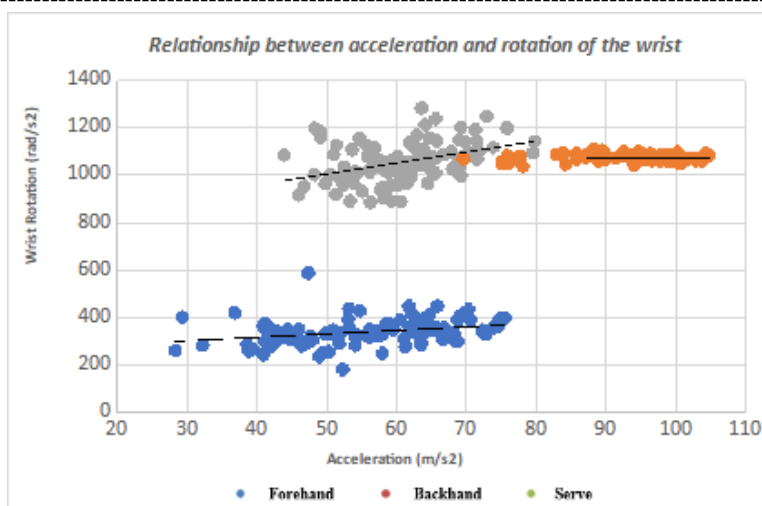
Athlete	Weight (Kg)	Height (cm)	Age	Gender	Arm Length (cm)	BMI
A	57	168	18	M	72	20,2
B	53	158	15	F	67,5	22.08
C	55,4	169	15	M	73	19,7
D	82	174	25	M	74	27,3
E	84	170	33	M	73	29,1
F	48	160	23	F	69	18,8

Table 2; Average Data and Std. Deviation of the study group

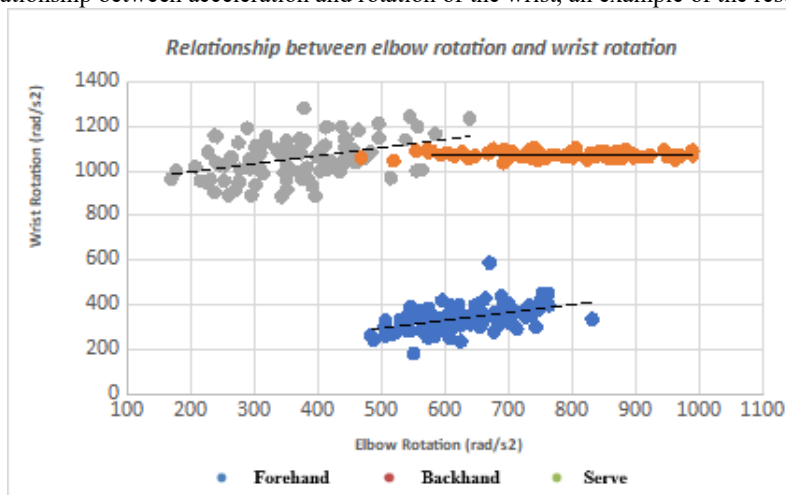
	Forehand Topspin			Backhand Topspin			Serve		
	Acc.	Elbow Rotation	Wrist rotation	Acc.	Elbow Rotation	Wrist Rotation	Acc.	Elbow Rotation	Wrist Rotation
Average	33 m/s ²	694 rad/s	552 rad/s	61 m/s ²	314 rad/s	643 rad/s	70 m/s ²	480 rad/s	1153 rad/s
STD. Dev	10	34	138	46	228	478	5	45	64



Graphic 1; Relationship between acceleration and rotation of the elbow, an example of the results for an athlete



Graphic 2; Relationship between acceleration and rotation of the wrist, an example of the results for an athlete



Graphic 3; Relationship between elbow rotation and wrist rotation, an example of the results for an athlete

Discussion

It is the first time that an advanced inertial technology instrument of this type has been applied to table tennis, capable of detecting translations and rotations of the instrument anchored to the body with extreme precision. Given the amount of interesting data, there are many reflections. What was initially noticed is an average acceleration data with the backhand stroke greater than the average acceleration data in the forehand topspin. In the table tennis culture, it is known that the forehand expresses more power than the backhand due to the very movement of the fundamental in which during the forehand topspin, the body is used more and the weight discharge on the ball is very significant.

This seems at first glance to be discordant with the results obtained, considering that it was found in all six types of players. Recalling that the K-Track was positioned on the wrist and not on the back as in many studies presented, the first data provided is therefore that during the execution of the backhand topspin, an acceleration of the arm is required, the highest compared to the other two fundamentals (forehand topspin and serve). And this is a new element that will direct the training plan towards certainly different, more adequate work parameters.

The wrist, elbow, and shoulder, although part of an open kinetic chain movement, are obviously closely related, however, wrist rotations were decidedly more significant than those of the elbow and shoulder in all fundamentals, indications that clearly go taken into account when planning your training. Going to analyze in more detail and correlating the shots with each other, it has been shown that the rotation of the elbow takes on a greater rotation during the backhand topspin, while in the serve we find the greater rotation of the wrist. From the correlation of the blow with elbow rotation and subsequent acceleration of wrist rotation, it was found that:

ELBOW ACCELERATION AND ROTATION:

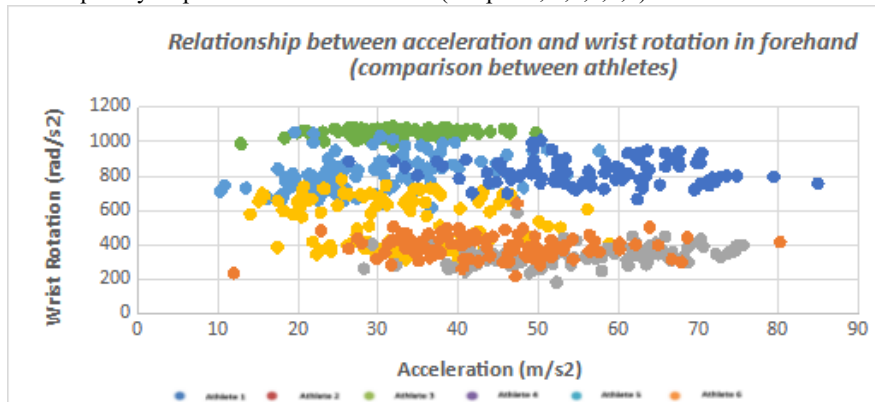
- ☐ STRAIGHT TOPSPIN, different accelerations can be obtained with similar rotations.
- ☐ BACKHAND TOPSPIN, similar accelerations can be obtained with different rotations.
- ☐ SERVICE, you can get similar accelerations with similar rotations.

ACCELERATION AND WRIST ROTATION:

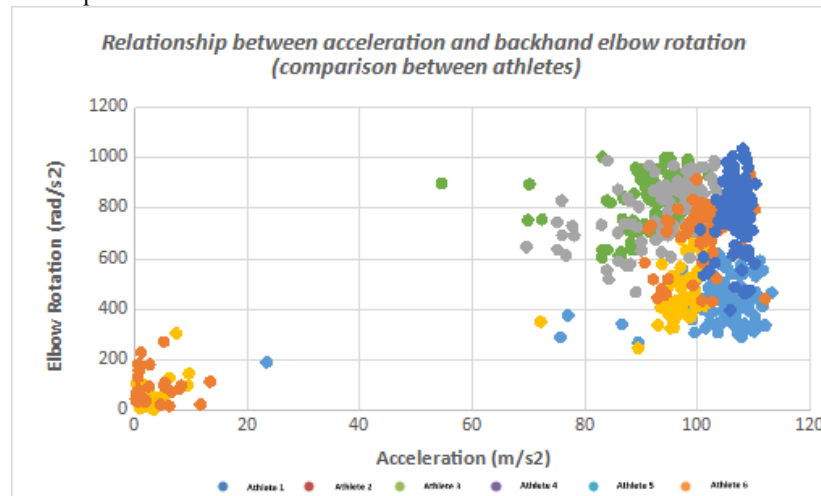
- STRAIGHT TOPSPIN, you can get different accelerations with similar rotations
- BACKHAND TOPSPIN, you can get similar accelerations with similar rotations
- SERVICE, you can get similar accelerations with similar rotations

From these data we can deduce that during the execution of forehand topspin, the rotation of the elbow is not strictly correlated with the acceleration because different accelerations can be obtained with the same rotation of the elbow, therefore it is not this technical part with which speed is expressed during the execution of the stroke. We find the same thing by correlating forehand topspin with wrist rotation, so we can deduce that in this fundamental the upper limb has a directional role and is not essential for expressing speed on the shot. From these data we can deduce that during the execution of forehand topspin, the rotation of the elbow is not strictly correlated with the acceleration because different accelerations can be obtained with the same rotation of the elbow, therefore it is not this technical part with which speed is expressed during the execution of the stroke. We find the same thing by correlating forehand topspin with wrist rotation, so we can deduce that in this fundamental the upper limb has a directional role and is not essential for expressing speed on the shot. By correlating the acceleration with the rotation of the elbow in backhand topspin it is noted that with similar rotations different accelerations can be obtained therefore also in this case the rotation of the elbow is not correlated in imparting speed to the ball, instead, the rotation of the wrist during the backhand topspin execution and acceleration are related because similar rotations result in similar accelerations.

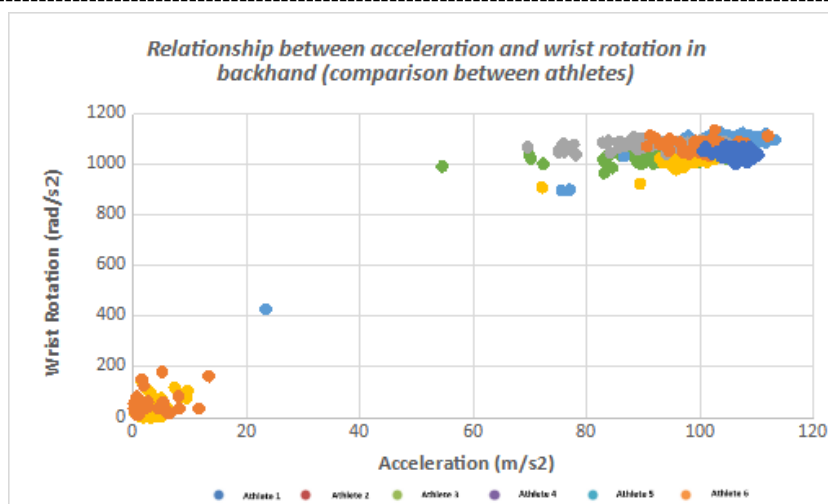
During the execution of the serve, a strong correlation was recorded between elbow rotation and acceleration and wrist rotation and acceleration because in both cases similar rotations result in similar accelerations. So, in this fundamental, the two rotations and therefore the use of these two articulations is closely correlated with the acceleration and therefore with the speed that can be imparted to the ball, therefore with the effectiveness of the shot itself. It has also been noted that although the serve is a shot in which you start from a standstill, the acceleration detected does not differ much from the other two fundamentals (which are in motion), therefore great explosiveness of the upper limb in play is decisive. In the specific graphs, it is noted that some subjects in certain fundamentals almost always express the same technique, as if the strokes were all the same (acceleration and rotation data overlap each other), showing a high safety index in the execution of the gesture and therefore consequently of precision in its execution (Graphics, 4,5,6,7,8).



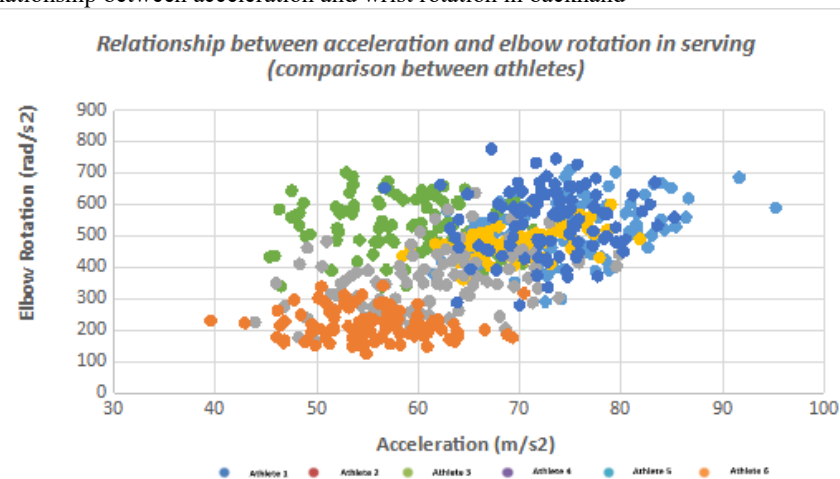
Graphic 4; Relationship between acceleration and wrist rotation in forehand



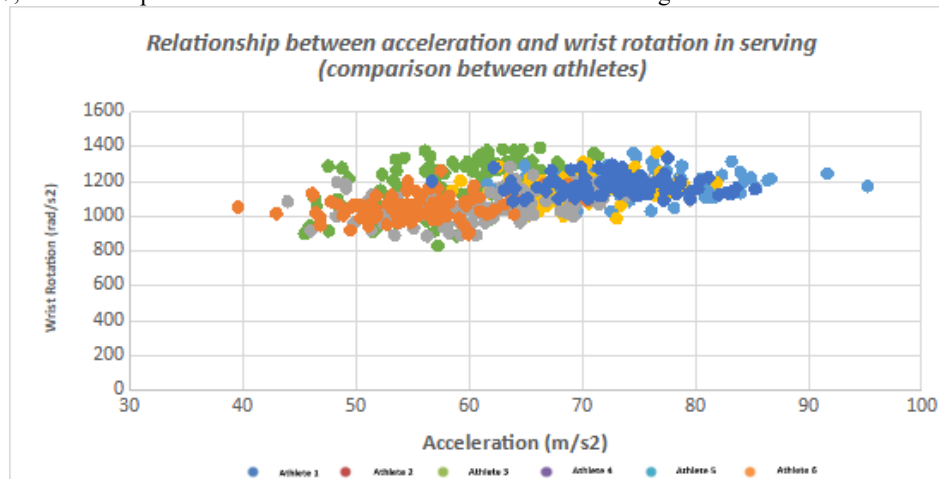
Graphic 5; Relationship between acceleration and backhand elbow rotation



Graphic 6; Relationship between acceleration and wrist rotation in backhand



Graphic 7; Relationship between acceleration and elbow rotation in serving



Graphic 8; Relationship between acceleration and wrist rotation in serving

Conclusions

In this research work, we wanted to analytically test the use of inertial sensors with a particular method, such as the positioning of the device, the quality of the same, and some elements that in our opinion could be decisive as clear and indisputable performance indicators and therefore the qualities expressed by the table tennis player. The objective was to validate the use of the tool in the aforementioned ways and therefore to make the analysis of the performance objective and scientific and to support the experiential choices of the technical staff. The data collected were multiple and innovative given the absence of similar works and comparable protocol modalities in table tennis. The results were very significant and precise and allowed for greater clarity on the role

and importance of the arm and the rotation of the elbow and wrist in the three different fundamentals analysed: forehand topspin, backhand topspin, and service. It is clearly noted that: in all three fundamentals the pulse is widely used; the acceleration of the arm in the backhand plays a main role, while in the forehand it has a directing role; It is clear that systematic analytical monitoring during the sports season would make it possible to make immediate, ongoing corrections to the work plan of the athlete(s), both from a physical-athletic and technical point of view, and to arrive at an even more complete with data detectable to a real index of objective evaluation of the athlete (PEI, Physical Efficiency Index, and TEI, Technical Efficiency Index).

The relevant observations can be many for the technician and for the physical trainer such as being able to clearly define which part of the anatomical components of the body are responsible for any problems encountered, or quantitatively define the preferences on the use of the different techniques by the athlete to rebalance, where deemed necessary or useful, the elements in a technical or tactical-strategic sense. The same can be said from a physical point of view where the data collected by the instruments can suggest a need for a dosage of exercises to remedy the problems of any lack of strength or speed of execution of the technical elements.

Author Contributions:

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

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References

- Alessandro Moura Zagatto, Miran Kondric, Beat Knechtle, Pantelis Theo Nikolaidis, Billy Sperlich. Energetic demand and physical conditioning of table tennis players. A study review. *Journal of Sports Sciences*. 2018, Vol. 36, 7.
- Baca, P. Kornfeind. Real time detection of impact positions in table tennis. *Biomechanics and kinesiology science* . 2010.
- Billi, Umberto. *Tennistavolo fondamenti tecnici, teoria e metodologia dell'allenamento*. 1984.
- Eric Boyer, Frederic Bevilacqua, Francois Phal, Sylvian Hanne-ton. Low-cost motion sensing of table tennis palyers for real time feedback. *Sports Science*. 2013.
- Goran Munivrana, Gordana Furjan-Mandic, Miran Kodric. Determining the structure and evaluation the role of technical-tactical elements in basic table tennis playing systems. *International Journal of Sport Science & Sport*. 2015, Vol. 10, 1.
- Hui Zhang, Wei Liu, Jin-Ju Hu, Rui-Zhi Liu. Evaluation of elite table tennis players' technique effectiveness. *Journal of Sport Sciences*. 2013, Vol. 31, 14.
- Isao Hayashi, Masaori Fuji, Toshiyuki Maeda, Jasmin Leveille, Tokio Tasaka. Extraction of knowledge from the topographic attentive mapping network and its application in skill analysis of tabletennis. *Journal of human kinetics* . 2017, Vol. 55.
- Ivan Malagoli Lanzoni, Rocco Di Michele, Franco Merni. A notational analysis of shot characteristics in top-level table tennis players. *European Journal of Sport Science*. 2014, Vol. 14, 4.
- Malagoli Lanzoni Ivan, Lobietti Roberto, Merni Franco. Footwork in relationship with strokes and efficacy during the 29th Olympic Games Table Tennis final . *International Journal of table tennis Sciences*. 2010, 6.
- Strino, Flavia. *Tennistavolo teoria dell'allenamento*. 1987.
- Sho Tamaki, Kazuto Yoshida, Koshi Yamada. A shot based approach to performance analysis in table tennis. *Journal of human kinetics*. 2017, Vol. 55.
- Shu-Chuan Shiei, Ju-Ping Chou, Ying-Hao Kao. Energy expenditure and cardiorespiratory responses during training and simulated table tennis match. *Internation Journal of table tennis Sciences*. 2010.
- Izzo, R., Giovannelli, M., Raiola, G. (2019). Training load in elite goalkeepers with K-Track for monitoring performance, *Journal of Physical Education and Sport ® (JPES)*, Vol.19 (Supplement issue 5), Art 280, pp. 1890-1896, 2019 online ISSN: 2247 - 806X; p-ISSN: 2247 - 8051; ISSN - L = 2247 - 8051 © JPES.
- Yoichi Iino, Takeji Kojima. Kinetics of the upper limb during table tennis topspin forehands in advanced and intermediate players. *Sport Biomechanics*. 2011, Vol. 10, 4.