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DEGREE END PROJECT

Bibliographical review of the block start biomechanics in sprint events

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Degree in physical activity and sports sciences

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1. Abstract:

Being the block start a crucial part of any sprint events, many authors have sought through investigations ways of performing the block start by analysing kinetic and kinematic parameters (Bezodis, Salo, & Trewartha, 2010) (Bezodis, Salo, & Trewartha, 2014) (Bezodis N. E., 2009) (Davila, Campos, & Dapena, 2006) (Debaere, Aerenhouts, Hagman, & Jonkers, 2012) (Favérial, Basset, Mborou, & Teasdale, 2000) (Milanese, Bertucco, & Zancanaro, 2014) (Čoh, Tomažin, & Štuhec, 2006) (Slawinski, et al., 2009) in order to find which ones are the most important regarding block start performance, and, if it is possible, to create a "golden standard technique" or positioning that would make athletes perform the best block start they could. There have also been tries to find new ways (not accepted by the IAAF (International Association of Athletics Federation)) to see if by changing the starting devices or placements at the blocks (Brown, Finch, & Ariel, 1999) (Korchemny, 1992) (Otsuka, Kurihara, & Isaka, 2015) athletes could improve their performance but unluckily with no evident results. In this review, due to the fact that authors have different opinions about until when is considered the block start, I´d like to mention that I have only done the study until the first touchdown after leaving the blocks.

The three main conclusions of this review are, firstly, that some of the kinetic and kinematic parameters that are discussed (such as the amount of RFD (ratio of force development), the importance of exerting force with the rear leg, the importance of swinging vigorously the arm in the first stride or the placement of the centre of mass) do enhance block start performance if correctly done. Secondly, that some kinetic and kinematic parameters are linked (such as centre of mass placement and force exerted by the arms). And the third main conclusion is that nowadays, there is still not a "golden standard way" of starting from blocks, but some general ways of performing the "set" stance and the block start that usually give the best results.

2. Introduction:

Since block start devices were introduced to sprint events in 1928-1929 (Bezodis N. E., 2009), sport researchers have tried to find the best way of using this device in order to obtain the biggest benefits from it and enhance athletes block start performance. For that, many investigations have been done with the aim of searching which kinetic and kinematic parameters were the ones that enhanced block start performance the most (Bezodis, Salo, & Trewartha, 2010) (Bezodis, Salo, & Trewartha, 2014) (Bezodis N. E., 2009) (Debaere, Aerenhouts, Hagman, & Jonkers, 2012) (Favérial, Basset, Mborou, & Teasdale, 2000) (Slawinski, et al., 2009) and even some of them proposed new devices or ways of starting from blocks to see if better performances were obtained (Brown, Finch, & Ariel, 1999) (Davila, Campos, & Dapena, 2006) (Korchemny, 1992) (Otsuka, Kurihara, & Isaka, 2015).

The main aim of this review is to determinate which kinetic and kinematic parameters enhance block start performance. Due to discrepancies between authors regarding until when is considered the block start phase, I must mention that in this review I only studied and discussed different parameters until the first touchdown after leaving the blocks.

Thus, the objectives of this review are to:

- Determinate which kinetic and kinematic parameters can enhance block start performance.
- Determinate if any kinetic and kinematic parameters are linked.
- Determinate if there is a golden standard for the block start .

3. Methods:

3.1. Searching strategy:

For this research, I've used "PubMed", "Google Scholar" and "Research gate". The research of information for this degree end project started the 28/12/17 and finished the 23/4/18. For searching articles, the strategy I used was the following: As my degree end project subject is the biomechanics of the sprint start, I followed two different research paths.

On the one hand, I looked for articles that talked or discussed about overall block starting technique kinematics, in other words, how is the sprint start technique (feet placements, block angles…) usually taught to athletes while being in their athletic teams, and which are the principles behind those lessons. For this, I tipped in all the websites mentioned before combined sentences that contained the following words "sprint start" 148.343 results, "block start" 3.641.526 results, "sprint start technique" 107.029 results, "block start technique" 2.501.184 results and "block start training" 1.240.142 results.

On the other, I searched for articles in which investigations had been performed in order to determinate kinetic and kinematic aspects that were proven to enhance performance. The way of looking for these articles was the same as in the first case but changing the tipped words on the browsers to "Kinematics of the block start" 77.066 results, "Kinetics of the block start" 524.143 results, "Kinetics and kinematics of block start" 24.832 results, "Kinematics of the sprint start" 6.564 results, "Kinetics of sprint start"16.967 results and "Kinetics and kinematics of sprint start" 9.082 results.

Also, some of complementary information used in this work was obtained from different subject class notes from the sport sciences degree I did.

3.2. Inclusion and exclusion criteria:

When deciding whether I should include or not an article in my work, I considered three main criteria:

- The investigations had to use a starting block device.
- The investigations had to analyse kinematic and/or kinetic parameters.
- In investigations, participants should be at least sub elite athletes.

Any article found that didn´t fulfil these aspects was put aside.

3.3. Languages of research:

For this research, I've tipped the key words or sentences previously mentioned only in English.

4. Term definitions:

Before analysing and discussing about the data, let´s start by defining the two main terms that will mostly be mentioned from now on.

Those two main terms are the kinetic and the kinematic parameters.

Kinetics comes from "kinesis" (Greek) which means pertaining to movement. Kinetics studies motion and its causes, which are forces such as torque, gravity or friction. Kinematics, in contrast, are responsible for the study of motion without considering any of the forces acting upon the body in motion (2015, December). Relating it to our subject, we could say that kinematics would study parameters such as block angles, hip position at set stance, distance between blocks… while kinetics would study forces induced to blocks, efficiency of applied forces to the ground or weight distribution during set stance.

5. Data analysis:

For this work, I made an analysis of which kinetic and kinematic parameters are determinant, or at least of great help, to perform an optimal block start at any sprint athletic event. After collecting the data from different articles, I decided to present them in two different blocks, one for kinetic parameters, and another for kinematic ones. Furthermore, in each block, data will be divided within different subgroups.

5.1. Kinetic parameters:

5.1.1. Power changes after increasing between leg width

All athletic events up until 400 meters demand to start from starting blocks (IAAF, 2015), this starting block are regulated by the IAAF (international association of athletics federation) normative (IAAF Certificate E-99-0121). The IAAF doesn´t give specific measurements about the blocks but instead, what they release is a list (IAAF, 2018) with the names of companies and products that they consider they are valid to use in competition. I´m mentioning this as an introduction due to the fact that we must keep in mind starting blocks have some characteristics that can (block angulation) and cannot (width between blocks) be changed by each athlete while preparing the blocks previously to a start.

Thus, kinematic analyses are usually done using the block dimensions allowed by the IAAF, but as we cannot ensure the actual starting device is the best that will ever be made, some researches are investigating new start devices or stances that could be better (Otsuka, Kurihara, & Isaka, 2015) (Brown, Finch, & Ariel, 1999). In the first of these investigation, they had seen a study that said that the squat at the gym, which has a movement and limb position pattern really similar to the ones made at sprint start, when performed with a wider

stance, generated stronger muscle activations in lower limbs. With the thought that this could enhance block induced power made by hips, they made fourteen athletes start a sprint with a 140% shoulder width on the blocks to see if there was any enhance. The study ended revealing that no significant changes were seen in normalised block induced power compared to normal, suggesting the new position didn´t have a significant response. This situation was also corroborated by (Brown, Finch, & Ariel, 1999) Gill company, which developed a non-valid (by the IAAF rules) start blocks in which there was the possibility to regulate up to a 16º angle the width between the blocks. Again, the results obtained were not significant even though they obtained greater lineal velocities, but in any case, we must remember that in both studies athletes weren´t used to start from these stances and that fact could have polluted the results. Even if they enhanced performance, these blocks nowadays wouldn't have had an impact on performance, since the IAAF doesn´t allow using starting blocks that can be widened between both blocks. But still, they can be helpful for the invention of future starting devices that might end being allowed in competitions.

5.1.2. Leg pre-stretching at "set" stance:

In a study in which some stances and ways of starting from blocks were discussed (Korchemny, 1992), there is a mention to a fact of great interest for the sprint start. Muscles have the ability to, with a previous stretch, load with what we call the elastic force, and use it to increase the total strength they can apply when contracting concentrically (Orbañanos, 2017). So, in order to increase the total force applied to the blocks when starting, the author recommended applying greater isometric forces against the block during the set stance, so specially the ankles got "elastically loaded" and thus, when starting the sprint, the total force exerted against the blocks would be higher. This statement on a first glance might look like it could be of a great help.

Unluckily, another study (Davila, Campos, & Dapena, 2006) results didn´t completely agree with the previous idea. In this study, thinking that a good start is usually characterised, between other aspects, by exerting great forces against the blocks in the set stance, also tried using to the elastic properties of the ankles to produce bigger amounts of total concentric force against the blocks by maintaining greater isometric forces at the set stance to see if this helped the start. What they didn´t realise at the beginning is that, to be able to maintain that position in which the athletes are exerting bigger forces, arms must also produce bigger efforts backwards in order to create a neutral force between frontward and backward forces, so athletes don´t move at set stance. The problem came when after investigating they realised that muscle doesn´t deactivate instantly, it needs time, and the more activated they are, the more time they need to deactivate. This study ended up concluding that, in fact, a block muscle pre-tensing would clearly help block starting because it would allow athletes to induce greater forces against the block, but that, due to the time arm muscles need to deactivate the backward forces that they are exerting to obtain that neutral stance, all force gains were annulated. Again, we must mention that results could have been polluted by the lack of practice of the athletes with this starting technique. Maybe being able to calculate the right amount of strength against the blocks that each athlete should exert so when deactivating the arm backward strength wouldn´t neutralize all the forward elastic gained force could highly help improving block start performance, but further investigations must still be done to clear this theory.

5.1.3 The importance of impulse at block start:

Related to this last discussed point, some people might think that the best sprinters will be those that can produce higher forces against the blocks. A common thought could be that the stronger athletes would be the ones that start better, but this is not exactly true. If that was the case “strongmen” would have the best start from blocks. A study (Slawinski, et al., 2009) that analysed diverse

kinetic and kinematic aspects of the sprint start, suggests that a greater impulse explains the ability to leave the starting blocks at high velocity. In fact, it was seen that impulse was greater in elite sprinters than well trained sprinters. As the study explains, the impulse of a movement is defined as the area under the force-time curve. This area´s size depends on 3 main parameters that are the duration of force application, the RFD (rate at which strength is developed through time) (Cámara, 2018) and the reached force peak. The problem with quick limb movements is that the short contraction time doesn´t allow the muscle to achieve its maximal force. In the experiment that was carried out in this article it was shown that there was no significant difference between the duration of force application between the elite and well-trained sprinters. Then, we must assume that the difference between them is not due to time exerting force against the blocks but by the amount of force they can apply in the same time, meaning that athletes with a RFD that reaches higher force peaks in the same time will achieve better sprint starts. Therefore, any increase in RFD becomes highly significant because it allows higher level of muscle force to be reached in the early phase of muscle contraction. In this investigation maximal acceleration was achieved in less than 0,150 seconds, hence, RFD is a crucial parameter in the ability to leave the blocks.

With this last paragraph, what I wanted to make clear is that, this far, we have seen that exerting great levels of force against the blocks is crucial to perform a good start, but athletes must be capable of producing them in a really short time, so they are be able to leave blocks as quickly as possible.

5.1.4 The importance of using more the rear leg at the start:

In other study (Bezodis et al. 2014) in which they experimented with 16 elite and well-trained sprinters, their aim was understanding some specific aspects of technique that were associated with higher levels of block phase performance. One of the main findings of the study was that when rear leg´s force contribution increased, also block phase performance did. Due to the set stance, the rear

leg extends over a smaller range than the front one, which usually makes athletes of lower level to mostly use the front leg to take off from starting blocks. This fact can easily be seen in beginners at any athletics track. Nevertheless, this investigation showed that longer rear leg pushes, as a percentage of total push duration, were also associated with higher levels of external power production, which is the power contributing to translate the centre of mass (Bezodis N. E., 2009). Thus, being able to distribute power production in a better proportion between both legs will ensure a much better block start.

5.1.5. Arm importance at “set” stance:

As we have previously mentioned, the use of starting blocks is mandatory in sprint events up to 400m. Overall kinematic positioning will be discussed in the next block but it’s worth remarking that, as it can be seen at any athletic competition, the usual set position is quite unnatural and uncomfortable. The unnatural and uncomfortable position that athletes achieve by using the blocks is due to a seek of an imbalanced stable state (Rocandio, 2016). Imagine a man or woman standing on both legs who is about to start running, they can´t instantly start applying force backwards, but firstly they´ll always slightly bent the knees and trunk while they let themselves fall forward before starting to apply force in the backward direction. Athletes look after that imbalance because it helps us to start running.

Until 1928-9 that blocks were introduced into competitions (Bezodis N. E., 2009) people already used to dig holes on the floor (made of ash) to put their feet in them and simulate some kind of starting blocks, or at least start from forward leaned positions which some of them looked like the ones athletes use in current competitions (June, 2016). As it can be seen, probably even without knowing why, athletes from the past used that kind of positions because the felt that starting that way was easier despite being uncomfortable.

The explanation behind this search of forward leaned positions is that, when we want to start running, some first strong strides backwards horizontally directed

are needed, and if we are standing, is hard to apply that required horizontal force. To start running from standing up, firstly the balance used for it must be broken in order to lean forward, so we can start applying that horizontal force. This process of breaking the initial balance takes some time, that's why by using starting blocks or forward leaned positions, athletes are able to save some time in the start (Rocandio, 2016).

Having explained the reason and the importance behind using the forward leaned position, it´s vital to know which the arms duty in this set stance is. As we´ve seen this far, the best way to start a sprint is by creating an imbalance situation in which the balance that the body uses to stand has already be broken, so the force can be directly exerted backwards and save time in the start. But in order to achieve this unbalanced position without falling to the ground, the arms are responsible for holding the body by applying enough force. This doesn´t mean they support all the bodyweight, just about the 25-40% of the bodyweight is the common trend nowadays (Rocandio, 2016), but nevertheless, without the arms, being able to maintain the body so forwardly leaned would be impossible.

5.1.6. Arm momentum at first stride

Another interesting fact about the arms in the sprint start is the first swing they perform. As a study mentions (Korchemny, 1992), the role of the arms on the first stride, which occurs as the athlete "jumps" off the blocks, is of great help if the athlete is able to do it in a vigorous manner. The reason is that, in the same way as the arms help in the abalakov jump gaining extra height, the arms, when swung vigorously and correctly, give an extra momentum that helps athletes to leave the blocks. It is true that because the arm is already extended to 90º approximately on the "set" stance, and because a stretch shortening cycle with the front portion of the shoulder, the chest and the coracobraquial muscles can't be performed (which are the biggest responsibles for the rising of the arm (Ezquerro, 2003)) as the athletes don´t have time to perform it , the gained

momentum and the gains in time obtained by it won't be high, but in the start of an athletic sprint event, a situation that longs for much less than half a second, even the tiniest difference between athletes will mean winning or losing (Reis & Fazenda, 2004).

5.1.7. Arms used for leg pre-stretch:

There is other parameter I'd like to mention about arm kinetics that is linked to a study that has already been previously mentioned in the leg Kinetic parameters (Davila, Campos, & Dapena, 2006). We´ve mentioned before that the aim of the arms on the "set" stance is to hold the body in the position in which the athletes think they´ll achieve the best start, in other words, create a stability in which the body of the athlete maintains the wished position without moving (Rocandio 2016). For that, the arms must exert a determinate amount of force backwards which will almost totally depend on how much force are the legs exerting on the blocks. The more you are trying to push against the blocks with the legs, the bigger force you´ll need to apply backwards with the arms to achieve that neutral force that the "set" stance requires. The most extreme example would be the one mentioned already in the study about pre-stretching the ankle muscles, in which the athlete, trying to benefit from the elastic capacity of the muscle, exerted bigger amounts of force against the blocks. In this case, the amount of force produced by the arms needed to obtain the stable set position would be much higher than in an athlete that is just supporting the feet on the blocks.

5.1.8. Leg exerted power and its orientation at block start:

Being in sprint short events reaching first the finishing line the way of determining who is the winner, the key performance indicator for these competitions is time, but it is power production which determinates this (Bezodis

N. E., 2009). The one who is capable of running the whole distance in less time will win, and for being capable of running in less time the athlete must produce higher values of power from the beginning of the race.

In order to translate forward, the force that athletes exert must be oriented backwardly against the blocks, this way their body will advance towards the finishing line. But is the rate at which they can do this work that will determine their performance. This means that for achieving a good start, the amount of force the athlete exerts and the velocity at which he is capable of exerting it will be two crucial factors. This backwards applied force amount and the velocity at which is applied are quantified by the horizontal external power exerted against the blocks (Bezodis N. E., 2009).

Normalised average horizontal power has been identified as the most appropriate measure of performance in the sprint start, as it was stated in another study regarding the same subject (Bezodis, Salo, & Trewartha, 2010). Due to the fact that the choice of performance measure can clearly influence reached conclusions in studies, selecting normalised average horizontal power is the best choice because in a single measure, it objectively reflects how much an athlete is able to increase his velocity and the associated time taken to achieve it, while accounting morphological variation between athletes.

As it has been shown (Bezodis N. E., 2009), a greater block performance phase with high amounts of horizontal external power applied against the blocks does not affect flight time nor step length in following phases. Thus, striving to increase that horizontal external power with the idea of enhancing performance is a good strategy that won't affect negatively upcoming kinetics nor kinematics.

5.1.9. Risks of powerful block starts:

Nevertheless, this last-mentioned statement has to be cautiously taken into account. It is true that, in fact, as the previous study has shown, performing a powerful and quick block start will not negatively affect the athlete's performance in the following accelerating phases. This was confirmed in

another study (Bezodis, Salo, & Trewartha, 2014) in which not only they saw that great horizontal power outputs did not affect following phases, but it also was associated with a better first touchdown position in which applying horizontal power was eased. But these positive effects will only occur as long as the athlete´s body is capable of baring that effort.

As another study stated (Korchemny, 1992), the problem was that just focusing on a powerful starting effort could lead to an uncontrolled momentum due to a lack of ankle stiffness or balance during the first touchdown with the ground. This disturbance carried the need of applying more effort in order to regain the horizontal power application and thus acceleration. This whole process of recovering from that uncontrolled situation takes time, which is the opposite of what we are striving for in sprint events.

When training our athletes, keeping this last statement in mind is of a vital importance. There are many studies that demonstrate the importance of performing a powerful start (Bezodis N. E., 2009) (Bezodis, Salo, & Trewartha, 2014) (Slawinski, et al., 2009) for achieving great starting performances, or the benefits that a powerful start might have, but as it has been seen in the last paragraph, coaches should also take into account that their athletes might not be capable of baring the first landing after that huge first powerful move.

5.2. **Kinematic parameters**:

5.2.1. Centre of mass at “set” stance:

The centre of mass of an object is the one point where the mass of the object is evenly distributed. It has been seen that the movement patterns of the centre of mass vary between athletes giving us a tool for evaluating technique. Its position depends on age, sex, body build, food, breathing and body (Bartlett et al. 2012). While being in the “set” position prior to start running, it has been shown that the placement of the centre of mass can influence the performance of the start. As one study states (Slawinski, et al., 2009), after analysing the

sprint of several elite and well-trained athletes, they discovered that the group of the elite athletes all placed their centre of mass closer to the starting line. It seems like by positioning the centre of mass closer to the starting line, the distance it must travel is decreased, which increases the velocity of the centre of mass in the pushing phase. Thus, considering ways of approaching the centre of mass of athletes to the starting line would a great strategy to improve block start performance.

The centre of mass parameter can also be used in order to assess the utility or effectivity of different starting devices or starting techniques. As it was mentioned in previous studies (Brown, Finch, & Ariel, 1999) (Otsuka, Kurihara, & Isaka, 2015) some investigators tried to analyse if a block starting device with a bigger width between blocks enhanced the start performance after seeing that when performing squats at the gym a bigger muscle activation was achieved when widening the distance between the legs. The kinetic aspects of these studies have been previously discussed in the kinetic parameter section of this review, but regarding the centre of mass, it can be seen that it can also be useful to determine if this new kinematic position is helpful. It was shown that (Brown, Finch, & Ariel, 1999) because of the width of the blocks, the direction at which the front leg pushed while performing the start was not as straight as when performing with the average blocks, causing the body to adopt a slightly deflected flying direction that caused the centre of mass to lean over the first step leg in excess. This mentioned over lean of the centre of mass caused an imbalance that disturbed the performance and required of an extra effort and time from the athlete to be able to recover, which meant losing time. Hence, using a starting device that makes the path of the centre of mass to be disturbed is of no use in a sport in which any millisecond is of a vital importance.

5.2.2. Trunk bent at block start:

It has also been described (Rocandio, 2016) that in order for athletes to be capable of performing the first step whilst applying the force in an horizontal

direction, the role of the trunk is of vital importance. It seems that, what enables the athletes to perform that correctly oriented step is to have their centre of mass ahead of the step, and is the trunk bent the responsible of easing that front placing of the centre of mass. Thus, in order for the athletes to apply the force in a better direction, placing the centre of mass ahead of the steps is crucial, and for this, bending the trunk will be the best strategy to ease this centre of mass placement.

5.2.3. Starting blocks placement:

The use of starting blocks is mandatory in sprint events up until the 400 metres event, including the first runner in the relays of the same distance events (IAAF, 2015). Because of this rule, trying to find the best ways of placing this starting device in order to obtain benefits that can help performing an outstanding start is essential for any athlete or coach.

Before thinking of any strategy, it must be kept in mind that there are some rules regarding the athlete's position on the blocks and the blocks themselves. Firstly, athletes must maintain the contact between their feet and the blocks all through the "on your marks" and "set" position. This means that strategies such as using only one leg against the blocks wouldn´t be allowed. Secondly, the starting block device has a standard built scrupulously supervised by the IAAF in order to be the same or very similar in all competitions. Some of these rules are that blocks must capable of changing their angulation from 30º to 80º or that the width between them in the lateral plane cannot be changed (Rocandio, 2016). Therefore, selecting different angulations, distances or positions on the blocks will cause different body limb trajectories, velocities, power outputs and orientations. As an example, the more open the block angle (closer to 90º) the more rectilinear the foot and trunk trajectory will be.

Since starting blocks began to be used at competitions, there have been three general block distance positions: The narrow, the intermediate and the wide start. The narrow way of starting is by placing the front block at 41 cm from the

start line and the rear block at 28 cm from the front block. The ones using this narrow distance, look after a faster start with high but fast force application simultaneously in both front and rear block. To be able to use this starting way in an efficient manner, athletes must be capable of exerting huge amounts of explosive strength.

The intermediate way of starting consists in placing the front block at 53 cm from the starting line and the rear block at 41 cm from the front block. With these distance measures athletes need more time to leave the blocks but they gain more speed due to a bigger time of force appliance. The last way of starting would be the wide start, in which the front block would be placed at 53 cm of the starting line and the rear block at 66 cm from the front block. The characteristics of this way of starting are that the time of force application is the biggest between all three ways of stating, that is the starting way that most time requires to be performed and that it helps acquiring good stride frequency with an appropriate length. Nevertheless, it also is the way that most energy requires to be performed due to the energy demand it has. Athletes don't exactly use these measures due to morphological issues, but they try approaching these values once they ´ve decided which type of start they´ll be using.

As it has been mentioned before, these three ways of placing the blocks are quite general, athletes choose approaching one or other way adapting it to his or her characteristics. On top of that, when choosing the distance between the blocks it is important to take into account the length of the event and the anthropometrical parameters of the athlete. For example, small and powerful athletes will tend to choose narrower start in order to perform a quick and powerful block start, so they can start performing the first steps faster and avoid the disadvantage of having shorter legs than other athletes. Regarding the event length, some starting ways take more time to be performed than others. Thus, if the event is a short one (60m dash for example), it's a nonsense to use the wide start which requires much more time than the narrow start, because although wider block positionings enhance block leaving velocities, the race is so short that athletes won't be able to catch the other sprinters on time.

Some studies (Bezodis N. E., 2009) (Reis & Fazenda, 2004), after developing some investigations, have come up with some placement measures with which

they say that the performance of the start, regarding placement parameters, is fully enhanced. The first study says the best results were obtained when the front block was at 47 cm from the start line and the rear at 35 from the front one. The second study doesn´t give the exact centimetres but they concluded saying that their research highlighted the fact that better performances were achieved when separation between blocks was higher and the front block was closer to the starting line.

It is true that in those studies, under their respective circumstances, those were the results (good performance), but we must be cautious when generalizing. In each of the studies, the distance the athletes ran and the way they were measured was a specific one. Moreover, the athlete's characteristics were not the same. With these statements it should be clarified that, for those investigators, with their athletes and their measuring methods, those block placements gave the best results, but coaches shouldn't think that those parameters will give equal results for their athletes in all sprints.

5.2.4. Knee angles at "set" stance:

The angles that the knees form while being in the "set" position have also been seen as a parameter to be taken into account in the block start. In fact, it has been said to be the factor that most conditions the "set" stance (Rocandio 2016). In the same way as the positioning of the blocks, the positioning of the knee angles is linked to the event length, being closed angles related to more powerful and quicker starts and thus, habitually used in shorter sprint events.

Due to force application distribution between both blocks when starting (longer application on front block), athletes usually choose to put the stronger leg in the front block and the more agile one at the rear. This placement happens because the front knee angle is always more closed (90º-105º) than the rear one (120º-138º), meaning that greater amounts of force will be needed to effectively come out of that closed angle at the front (Rocandio 2016).

Again, some authors (Slawinski, et al., 2009) ended their investigation with some values (front angle 90º to 110º and rear from 115º to 130º) that for them were the optimal ones due to the fact that they gave the best results. Caution is advised when interpreting this information due to the fact that our athletes aren't the same as the ones that took part in that study, and this without mentioning which distance was used in that study or which measurement devices or parameters were used for it.

5.2.5. Starting blocks placement on curved starts:

Other matter that is worth mentioning is how blocks are placed when the start is curve. Some athletic sprint events start in curve, this is the case of the 200 and 400 meters events in outdoor and indoor seasons, which due to the track built they both start in the curvilinear part. The main difference is in the direction at which the blocks are oriented, other parameters such as block angulation and knee angles are kept the same. In events that start in the curve, blocks must be placed looking for the tangent of the lane. This is done in order to decrease the centrifuge force that the athlete suffers in the first steps. If athletes started running without looking for the tangent, at one point, they would be forced to make a closed turn to avoid leaving their lane and thus being disqualified. Then, the centrifuge force could make them pass through hard times to maintain balance and acceleration. That´s why, so as to perform a good start in a curve, athletes must change the direction at which blocks are oriented (Rocandio 2016).

5.2.6. Arm positioning at "set" stance:

The orthodox way of placing the arms while being on the "set" position is by fully extending them, vertically from the shoulders but slightly abduced in order to

leave space for the legs and supporting the weight between the thumb and the index fingers while leaving the rest of the fingers in a pyramidal position gathered in the hand. This position is also slightly altered when performing a start in a curve. When this happens, the arm in the inside of the lane will be placed a little bit backwards so shoulders can be perpendicular to the block axis (Rocandio 2016).

The main role of the arms in the “set” position is to support part of bodyweight in order to create that stable instability necessary for a faster start, but this has been already discussed in the kinetic parameter section. Nevertheless, they also have a role in helping the centre of mass having a more advanced placement, and as we have also seen before, block start performance is enhanced when the centre of mass is placed closer to the starting line.

In order to bring closer the centre of mass to the starting line, arms must be loaded with more bodyweight, because by performing this action, by cause effect, we are bringing the centre of mass forward. Nonetheless, this action of loading the hands to advance the centre of mass has some risks. If by any chance an athlete puts too much bodyweight on the hands, he´ll be in risk of not being able to exert enough force against the blocks and his hip will fall down through the first steps (Rocandio 2016). Other way of loading the arms would be by increasing the distance between the hands or advancing the shoulders without moving the hands. It´s not clear which is the best way of placing the arms, but athletes must seek a position in which they are able of loading them in order to advance the centre of mass.

5.2.7. Hip placement and trajectory:

The placement of the hip in the “set” stance, as well as its trajectory during the first phase of the block start, is a kinematic parameter of great use in order to assess the performance of the start. Regarding its placement in the “set” stance, we can determine how powerful the start is going to be, or by looking at its trajectory we can determine if the “set” stance was correctly performed.

Moreover, depending of the event length, we can adjust its position in order to achieve placements more adjusted to the type of start the event requires.

The height of the hip is linked to the knee angles in the “set” stance, the higher the hip, the more extended they are. The height of the hip could be used as another kinematic parameter to determine if the “set” position adopted by the athlete in the event is adequate for the task. For example, it has been mentioned before that small or powerful athletes should use more closed knee angles in order to perform faster starts that need big amounts of explosive strength, and that this was linked to shorter events in which other type of slower starts weren’t recommended. Thus, for this kind of events or athletes, having a lower hip demands knee angles to be more closed, causing more power to be needed. So if the event demands a powerful and quick start, it would be a good strategy to consider lowering the athletes hip if it is in a high position.

The same would happen in the inverse case, taller or less powerful athletes should consider increasing the height of their hips in order to ease the start, even more if the event is a longer one (400m) in which the start isn´t as important as in the short events.

Analysing the trajectory of the hip when it´s leaving the set position can also give us information about if the “set “stance was being correctly done. It has been seen, that when an athlete performs a correct start, the trajectory that the hip executes is parallel to the ground, meaning that the athlete doesn’t make any vertical displacements. If the trajectory is not parallel it will probably mean that its placement at the “set” position was not correctly done or wasn´t the appropriate for the athlete performing it.

The two main hip trajectory alterations are when it is upwards and when it is downwards. The first alteration is majorly caused by a too low placement of the hip on the set position. The athlete, seeing he won’t be able to maintain balance once started accelerating, he or she starts exerting more vertical force in order to prevent that imbalance. That´s why we can appreciate how the hip trajectory starts rising instead of maintaining the horizontal trajectory. The second main problem is usually caused by a too high hip placement, that when the sprint starts, doesn´t allow the athlete to apply the force in the correct direction,

troubling the acceleration. That's why there´s a downward displacement of the hip trajectory, it's the athlete bending his or her knees and trunk in order to apply better the force.

6. Discussion:

This far, kinetic and kinematic parameters have been analysed separately and in an isolated way. The aim of this section is to discuss, on the one hand, about all the parameters that take part in the "set" stance and the first stride phase. And on the other hand, create links between different parameters and phases and see if there´s any possible "golden start technique" for starting from blocks.

To begin with, in the "set" stance, the block placement is crucial because is the device in which athletes will perform their "set "stance and from where they will perform their start (IAAF, 2015). As the IAAF has determined, each of the blocks used in competitions must be able to move in the sagittal plane and each block must be able to change their angulation from 30º to 80º degrees approximately (IAAF, 2018) (Rocandio, 2016). Block placement will be determined by the event length and the characteristics of the athlete. As it was mentioned before, there are three general ways of placing the blocks (narrow, intermediate and wide) having each their own advantages and disadvantages to take into account when selecting one for sprinting (Rocandio, 2016). Also, smaller or more powerful athletes are generally recommended to use narrower block placements in order to favour their abilities, as narrow starts are characterised for powerful and quicker starts. Exact block placements from the start have been proposed by some studies as the ones giving the best results (Bezodis N. E., 2009) (Reis & Fazenda, 2004) but it must be taken into account that those results were obtained with some athletes in some specific circumstances. Thus, generalizing their block placement measures is probably an error.

With different angulations of the blocks what we obtain are different trajectories of the body. The bigger the block angulation (closer to 90º) the more horizontal

the trajectory will be enhancing horizontal force application, but more power requirements will be needed in order to maintain balance. Conversely, smaller angulation angles don't require big power amounts, so is easier to start from blocks, but the trajectory is quite vertical so force applying efficiency will be decreased. Hence, depending on the athlete's experience and capabilities the angulation should be different.

There have also been some studies that tried augmenting the width between legs by creating special blocks that had that possibility (Brown, Finch, & Ariel, 1999) (Otsuka, Kurihara, & Isaka, 2015) after seeing that wider stances activated more the lower limbs. Nevertheless, as performance wasn´t enhanced and as the IAAF doesn´t allow that kind of starting blocks, strategies regarding the width of the leg stance are useless.

Knee angles are another parameter to take into account when performing the "set" stance. Again, as in the block placement, knee angulation is linked to the event length and the athlete's capabilities due to the fact that, for faster starts, more closed angles are needed. But it shouldn´t be forgotten they require bigger power amounts to be performed. Also, it must be kept in mind that, as the front knee angle will always be with a more closed angle that the rear knee, placing the strongest leg at the front block is vital (Rocandio, 2016). As in the block placements, there are also some authors that claim to have the best way to angle the knees, but again, those results were obtained with some athletes under specific situations (Slawinski, et al., 2009).

The role of the arms in the "set" stance has many functions. The orthodox way of placing them is vertically under the shoulder while being slightly abducted in order to leave space for the legs being the contact with the floor made with the thumb and the index (Rocandio,2016). The main function of the arms in the "set" stance is to maintain that instable stance that helps the start by eliminating the stability breaking phase. In order to perform this action, arms must support part of the bodyweight, being the common trend about the 25-40% of the bodyweight. Supporting higher or lower percentages could decrease the starting performance.

Another parameter that conditions the start performance is the placement of the centre of mass in the “set” stance. It was shown (Slawinski, et al., 2009) in an investigation involving elite and well-trained athletes that the fastest sprinters always placed their centre of mass closer to the starting line than the others. Then, it could be said that, to perform better starts, placing the centre of mass closer to the starting line would be a good strategy.

As one of the functions of the arms is to support part of the bodyweight, and as approaching the centre of mass to the starting line has been proved to be a good strategy, it could be said that there´s a connection between the last mentioned two parameters. When augmenting the bodyweight supported by the arms, due to body movement, the centre of mass is closer to the starting line. Thus, loading the arms in higher amounts in order to bring the centre of mass closer to the starting line could be a useful strategy.

Due to the elastic capabilities of the muscle, it was thought that by pre-stretching the ankle and knee muscles in the set position, athlete´s would improve their starting performance due to the gains of force that had been increased by that pre-stretch (Korchemny, 1992). Unluckily, what they didn´t take into account is that, to perform that pre-stretch, arms had to exert higher amounts of force backwards in order to maintain stability. Another study (Davila, Campos, & Dapena, 2006) showed that as muscles take some time to deactivate, gains in power by pre-stretching were nullified due to the time arm backwards exerting force needed to deactivate. Therefore, applying great amounts of force backwards with the arms in order to pre-stretch the leg muscles has been shown not to be useful.

One last parameter to consider in the “set” stance is the placement of the hip. The hip gives information about how the start is going to be. The lower it is, the more powerful the start will be, because in order to lower the hips, knee angles have to be more closed, needing more power. Also, if the hip is placed too high or too low, it can be assumed something is wrong in the overall placing of the athlete (Rocandio, 2016).

Regarding the first stride phase, it was described (Slawinski, et al., 2009) that greater ability to leave the blocks at high velocity was caused by impulse, being

the fastest athletes the ones that had greater impulse capabilities. The problem with sprint starts is that, due to the fact that they happen in a short period of time, muscles don't have time to apply all the force they are capable of applying. Hence, having a good RFD (ratio of force development) is vital for the start.

It has also been shown in other study (Bezodis, Salo, & Trewartha, 2014) that distribution of force exertion against the blocks between both legs is always imbalanced, being always the front leg the ones that applies force for longer time. Nevertheless, this study showed that best results were obtained when athletes were capable of distributing the force amount in a more balanced way between both legs.

The arm has also been seeing to improve the block start. A study (Korchemny, 1992) states that in the first stride, if the arms swing in a vigorous way, they help the set off from blocks by adding a momentum. This momentum can also be seen in the abalakov test.

As we have seen, in order to perform a good start, performing high amounts of force in very little time is crucial, nevertheless, this isn´t enough. As a study described (Bezodis N. E., 2009), in order to take full advantage of that force production, it has to be correctly applied. This means that in order to enhance acceleration, force production must be as horizontally applied as the athlete can, without losing speed or stability .This can be linked with the angulation of the blocks previously mentioned, the bigger the angles, the more horizontal the trajectory will be. Having the trunk in a bent position while performing the first stride as also been proved to enhance the application of the force in a more horizontal (and thus in a more efficient manner) way (Rocandio,2016) in the touchdown of the first stride.

One last parameter regarding the first stride phase is the trajectory of the hip. The trajectory of the hip is supposed to be parallel to the ground, if this trajectory rises or sinks would mean that the athlete wasn´t well placed on the blocks.

To sum up, firstly, a good "set" stance would be characterised by a good election of block placement, block angulation, knee angulation and hip

placement by taking into account the event length and the athlete´s characteristics. Also, Arm positioning and the weight they support should be taken into account in order to approach the centre of mass to the starting line while still being able to exert high amounts of force against the blocks.

Secondly, a good first stride phase would be characterised by a huge exertion of force against the blocks in a very small period of time, being this force well distributed between both legs and helped by the arm vigorous swing momentum. Also, force has to be well applied in a horizontal direction in order to enhance acceleration and in this task the role of the trunk helps when it is bent. One last parameter to consider in a good first stride phase is that the trajectory of the hip must be parallel to the ground.

7. Conclusions:

The main conclusions of this bibliographical review are, firstly, that, in fact, there are some kinetic and kinematic parameters that enhance block start performance. As we have seen, parameters such as approaching the centre of mass to the starting line or increasing the amount of force exerted by the rear leg have been proved to enhance performance.

Secondly, that some of the kinetic and kinematic parameters that take part in the “set” stance and the first stride phase are linked. For example, it is expected to achieve higher amounts of force exerted against the blocks if the angulation of ankles and knees at the “set” stance are more closed due to the power demand they have for starting.

Thirdly, that there is not a “golden starting technique” for a block start. As we have seen, this is due to factors such as event length, the athlete´s characteristics and the athlete´s subjective preferences. Nevertheless, throughout the review some general parameters have been discussed that have been proved to enhance performance. Thus, coaches should try approaching those general parameters or at least having them into when training sprint starts.

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