REVIEW ARTICLE

Laterality and performance in combat sports

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Abstract

Literature has shown a relationship between laterality and an over-representation of left-handed athletes in certain sports, and especially in sports one against one, such as judo, tennis, boxing or fencing; the main explanation has been attributed to greater chance of success. Some authors have explained it through a genetic or *innate superiority hypothesis*, however others defend the *strategic advantage hypothesis*.

The study aim is an overview about laterality, sporting success, over-representation of left-dominant athletes executing techniques, and the possibility of modulating that over-representation through training and based on *negative frequency-dependent selection hypothesis*, given that in sports such as fencing, boxing or judo, tactical designs and training actions have been developed based on the opponent's predominant side while executing skills.

It is hypothesized that if there is some sort of relationship between laterality and sporting success, and the laterality executing sporting skills has been acquired, then it can be modified by different learning and/or training methodologies; one of them is based on *bilateral transfer processes* of motor skills, but it is lacking on experimental research. We suggest that the notion of *creating* or *making* athletes from the perspective of the lateral preference running sporting skills and in sporting behaviours based on laterality, could modify the frequency-dependent selection hypothesis, especially in certain sports.

Key words: bilateral transfer • boxing • fencing • judo • left-handers athletes • sporting success

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Motor skills – *plural noun* the ability of a person to make movements to achieve a goal, with stages including processing the information in the brain, transmitting neural signals and coordinating the relevant muscles to achieve the desired effect [89].

Motor skill – a skill for which the primary determinant of success is the quality of the movement that the performer produces [90].

Reaction time – is the time from occurence of stimulus to first initiation of movement of the relevant segment of the body [90].

Reaction time (RT) – was determined by the time period, which started by lighting of LED and finished with the movement of epee goblet on a horizontal highly sensitive obstacle, which can was identified as motor response [91].

Position – *noun* **1.**the place where a player is standing or playing **2.** the way in which a person's body is arranged [89]

Visual acuity – *noun* the sharpness of someone's vision, especially as it relates to skills such as hand-eye coordination [89].

Introduction

Handedness is a specific term, and typically refers to the hand preferentially used for a simple (e.g. pointing) or a complex (e.g. writing) motoric activity, or to the hand that is more skilful at performing a task [1, 2]; besides, it is considered a universal and unique characteristic of all humans [2-5], and it reflects asymmetry of cerebral structure [6]; even some authors have suggested that its evolution is associated with the cerebral representation of language, particularly of speech [1, 2, 7], although recent studies have shown that chimpanzees and gorillas are also mostly right dominant, which refutes the idea that the right-hand dominance is an unique feature of the human species [8].

The preferential use of an upper or lower limb has been called *motoric dominance* [5]. This term refers to the usual measures of laterality accomplished by what hand or foot is preferentially used in a set of situations. Most general tests of laterality (i.e., indexes commonly used to assess or estimate handedness) are designed in this way [9-11]. In contrast, the term *functional dominance* refers to laterality demonstrated by the preference with which the athlete executes different sport skills.

Finally, the percentage of left-handed population is around 6% to 13% [3, 11-17] and left-handed men exceed left-handed women, so it seems to be that there is a significant sex difference [3]; thus, several hypotheses were formulated to explain that over-representation of right-handers in humans, some of them were hereditary, congenital, genetic, innate developmental or pathological theories [1, 2, 12, 18-20]; others were environmental or cultural theories [3, 21, 22] or also mixed theories [14, 23].

All these definitions, data and hypotheses will serve as a starting point for addressing the different sections of this review.

The study aim is an overview about laterality, sporting success, over-representation of left-dominant athletes executing techniques, and the possibility of modulating that over-representation through training and based on *negative frequency-dependent selection hypothesis*, given that in sports such as fencing, boxing or judo, tactical designs and training actions have been developed based on the opponent's predominant side while executing skills.

It is hypothesized that if there is some sort of relationship between laterality and sporting success, and the laterality executing sporting skills has been acquired, then it can be modified by different learning and/or training methodologies; one of them is based on *bilateral transfer processes* of motor skills, but it is lacking on experimental research.

Sporting success and over-representation of left-dominant athletes

Left-handedness is the preferential use of the left hand [24]. Literature has shown a relationship between laterality and sport, mainly between laterality and an over-representation of left-handed athletes, and many authors have focused on the over-representation of left-handers in certain sports compared to the general population; for instance, in tennis [17, 25-28], in fencing [11, 29, 30], in judo [31], in wrestling [32], in boxing [33, 34], in taekwondo [35, 36], in cricket [37], in ice hockey [38], in baseball [17], in volleyball [39], or in different sports [3, 11, 21, 40-42].

The main explanation that justifies the existence of a higher percentage of left-handed athletes in certain sports has been generally attributed to greater chance of success [5, 17, 25, 27-29, 31, 32, 37-39, 41, 43]. Anyhow, also disagreement on the reason that determines this sporting success exists [32, 41, 42].

The over-representation of left-handers does not happen in the same proportion in all kinds of sport. It has been reported [21, 40] that left-handers (or left-footers) appear to be more common (19.5%) in what are called *fast ball* sports, interactive sports, and in confrontational sports [4, 41, 42, 44, 45] such as, combat sports. Also, in cricket, 24% were reported (with the most successful teams having close to 50% left-handed batsmen) [37], 44% in floret, and 31% or 12% in sword [11], 25% in sabre [46], etc.

Other studies [3] involving sporting students and elite athletes (which were sorted in non-interactive and interactive sports) also showed that the ratio of left-handed sporting students and elite athletes were statistically higher than in the general population but, in this case, laterality of elite athletes was determined through the hand using the racquet, the bat, the bowl, the dart, the sword, etc., i.e., based on functional handedness, or *functional dominance*.

Sometimes, the laterality is determined by validated and verified tests (hand, foot, eye, ear) and/or surveys, which allows a classification of the athletes (left- or right-handers, left- or right-footers, etc.); thus, according to the laterality obtained by those tests and to a sport of reference, the percentages of left-handed players are extracted. The point is that being labelled like left-hander, or left-footer (motoric dominance), and having a sporting behaviour as left-dominant (functional dominance) could be different issues [47], i.e., it would be necessary to differentiate between morphological, gesturing, innate, or spontaneous laterality (as a manifestation of involuntary movement and spontaneous motor response), and functional, instrumental, neurological or tensional laterality (as the dominant motor skills acquired by interacting with the environment).

For all of these reasons above, we want to highlight the difference between being left-hander, left-footer or having a left body preference for turning, and using the left hand (or arm), the left foot (or leg), the left turn or a left position (southpaw stance) as a specific sporting behaviour while the athletes are performing different motor skills.

Therefore, it would be interesting to investigate about the relationship between the laterality of a subject (obtained by tests, specific questionnaires or surveys that have been used in research to determine the preference of hand, foot or turn) and the laterality regarding a specific sporting skill of the same subject, i.e., between *motoric dominance* and *functional dominance* [47-49]. It could be possible that a tennis player is filed as right-handed regarding tests and inventories to determine his laterality but, actually, uses a left-handed grip to play tennis. In this case, would the subject be right or left-handed? Would the player's success (using the left hand to play) also be associated with neurological innate characteristics (which appear to be more advantageous in tennis, like visual acuity, reaction time, etc.) despite being filed as a right-handed person? Or might it be that a tennis player benefits from tactical and strategic aspects derived from his own sport, and from the unusualness for his opponents to face a left handed player, regardless of how he is filed by the various tests?

In some studies, for example about the relationship between left-handed wrestlers (assessed by the Edinburgh Handedness Inventory) and sporting success [32], the statistical relation between left-handers and sporting success was already shown; however these studies do not reveal if the wrestlers' left-handedness is related to a preferred executing body side of fighting (left or right), or not. The same method was used to determine the relationship between left-handedness and success in boxing [33] and, once again, the left-handed boxers (assessed by the Edinburgh Handedness Inventory) were more successful. Therefore, the reason for this higher probability of sporting success might not be due to being classified as a left-hander (by general laterality tests), but rather due to executing on the left side (i.e. as a left-dominant athlete). In like manner, we should determine whether this over-representation in sport is due to be a left-handed person or due to executing as a left-dominant athlete.

If we take all this into consideration, it could be that the concept of laterality cannot be used as a general but only referred to as a particular skill or task, which may be sporting, or not. For example, it was suggested that the dominant hand does not necessarily dominate all performances, and Wang [50] wonders: for what the dominant hand is dominant? since, in fact, it appears that the functional superiority of the hand varies with the task. Therefore, it is necessary to determine the possible relation between the laterality that a subject had shown in tests and the laterality that she had shown while she was executing specific sport actions. We are also conscious that the direction of causality [40] should be specified, i.e. if a specific motoric dominance predisposes a person to choose a certain sport, or if sporting practice can influence motoric dominance, which is an important issue regarding studies about laterality.

Also in non-interactive sports the specialized use of one of the hands could have different meanings. It would be interesting to observe, in certain sports in which two hands are used (golf, baseball), if it necessarily means that the athlete is right-handed because he adopts an orthodox position. In fact, it has been shown, for example, that some professional golfers playing with the right hand were actually left-dominant people [40]. The reason for this modification of the laterality of execution by left-handed golfers could be explained in terms of a functional advantage. However, it was reported in ice hockey that all players who indicated left-handed dominance exhibited right-side shooting, while only 66% of right-handed athletes showed left-side shooting [38], which would preclude the use of innate theories to explain the left-handed superiority. The authors pointed out that the performance orientation is not correlated with handedness in ice hockey.

Other studies [47] also have considered that it is necessary to ask which is the relationship between laterality of use (*functional dominance*) and morphological or spontaneous laterality (*motoric dominance*). In another study [31], involving 90 judokas (13-14 years old) and linking laterality and judo techniques, the relationship between being labelled as left-handed, left-footed, right-handed and right-footed athlete and the usage of throwing judo techniques (forward-left, forward-right, back-left or back-right judo actions) was shown. Moreover, Mikheev et al. [51] suggested that during motor and postural skill acquisitions (long-term judo training) lateral preferences are modified, probably due to neuroplasticity, which could explain the results and the independency relations between *motoric* and *functional dominance* in judo.

Finally, and according to the results obtained from a population of athletes, 7% showed opposite preferences between hand gestures used in common gestures and sporting performances; furthermore, that percentage increased to 26.6% when referring to the lower body [11].

Regarding the lower limb, the preference for one leg is usually not as marked as the preference for one hand. It is easy to find children who kick and perform learned motor skills using one foot, but when they receive general instructions to execute a jump or stand on one leg they indicate a preference for the other. Cratty [52] demonstrated this lack of correspondence in the use of the legs in different tasks, stating that about 94% of the subjects preferred to kick with the right foot, but only about 65% used the right foot to execute various jumping tasks. In the field of sport research, studies have been less abundant; nevertheless, similar findings have been found in hurdles [53] or tennis [54].

Sporting success and laterality: innate vs. strategic hypothesis

The hypothesis that laterality may influence sporting performance, referring to the over-representation of left-handers in certain sports, is not new, as we have seen. However, some disagreements exist on the reasons that determine this sporting success [4, 32, 41, 42].

Some authors have presented a genetic or innate hypothesis for higher performance (*Innate Superiority Hypothesis*) [1, 11, 12, 25, 33, 55]. This hypothesis assumes that there is a central motor advantage (attentional advantage and neuropsychological advantage) [29] that favours left-handed athletes to have, for example, superior right-hemispheric abilities [11], better visuospatial abilities [56], superior spatio-motor skills, or a higher rate of bilateral representation of axial motor control [20]. Other authors have also found better results in left-handed athletes with regard to right-handed athletes in spatial orientation and attention, in visuospatial and gross visuomotor tasks and in neuroanatomic advantages while performing neurocognitive tasks [25]. Furthermore, left-handed athletes are favoured in evaluating perceptual patterns or rotation three-dimensional patterns [57], or in various coordinative aspects in certain actions [58]. Finally, some studies also stress that sporting performance (in fencing, soccer, running, skiing, boxing, badminton, baseball, tennis, etc.) is associated to some aspects of lateral preference [20] and, both of them (sporting performance and lateral preference) are associated with a sexual biomarker for prenatal androgen (testosterone) exposure called 2D:4D [59-62] (lower 2D:4D is associated, among men, with higher sporting performance and also with left-hand preference), highlighting again the innate character of laterality.

In contrast, other authors defend the strategic hypothesis (*Strategic Advantage Hypothesis*), which posits a different reason for the success of left-handed athletes [3, 5, 17, 21, 31, 32, 37-39, 42, 44]. In this one, success is explained by environmental factors (tactical and/or strategic) associated with handedness during sporting interactions. For example, some of the studies [21] stressed that the advantage of a possible higher proportion of left-handed players is low, but any excess of them would be due to the nature of the game, and not to any supposed neurological advantage. Similarly, the so-called *fighting hypothesis* [3] suggests that in combative situations left-handers have an advantage over right-handers since they are better adapted to fighting with right-handers since these are much more numerous; this is also our point of view and the starting point for our hypothesis.

In addition to these two previous hypotheses a further approach can be considered [4, 5, 41] in which the mixed nature-nurture of greater chance of success is defended, i.e., to not oppose nature vs. nurture, or heredity vs. environment, but to interrelate the two concepts. Therefore, and in certain cases, the nature vs. nurture debate would not be necessary because both theories would be present, suggesting the hypothesis of a double fragmentation in the genesis of the laterality structure which, on the one hand, would present an innate factor and, on the other hand, an educational factor that is expressed through the *laterality of use*.

Sporting success and frequency-dependent selection hypothesis

Frequency-dependent selection [17, 37, 38, 43, 45] is an important process in the maintenance of genetic variation in fitness; and, in humans, handedness is one of the traits for which the maintenance of a polymorphism is probably due to negative frequency-dependent selection [3].

Regarding to some authors, lateralization is not responsible for the increase in frequency of left-handers in a sporting population [3, 5, 44]. They agree with the *fighting hypothesis* (an evolutionary hypothesis) which is based on left-handers having an advantage when they engage in combat, due to the fact that they usually interact with right-handers, who are more numerous and, therefore, more accustomed to encounter other right-handers (familiar situation vs. unfamiliar situation). In ice hockey, Puterman et al. [38] showed that right-catching goaltenders saved 63% of shots, and left-catching ones only 49%. However, for skaters, right and left-shooters scored equally (33%), but when they faced right-catching goaltenders the right-shooters were more successful (29%) than left-shooters (19%). No differences were found when both shooters were faced with left-catching goaltenders (35% for left-shooters, and 33% for right-shooters). Similar results can be extracted from a study in football [63] in which goalkeepers anticipated right-footed kicks better than left-footed kicks.

In fencing, for example, many researchers and fencing masters agree on left-handers having an advantage over right-handers and on that this advantage was due to left-handers being a minority. Therefore, since the left-handers are a minority, they present less opportunity of knowing their tactics [30]. Another study [42] about the advantage of being left-handed in tennis showed that right-handed players were more predictable for right and left-handed players when they tried to predict the direction of strokes.

The over-representation of left-handers could be due to the *perceptual frequency effects* hypothesis. As it was stated, the left-handed attacks (mainly in interactive sports) are less frequent, thus the surprise effect should be taken in consideration for training. If the motor response to a left-handed attack were practiced, defensive reactions would be more automatic and, possibly, more effective, and the negative frequency-dependent would have less influence regarding the specific situations with left-dominant athletes. Furthermore, it was reported already that tennis players have preferences to place shots irrespective of their opponent's handedness [26]. As left-handers are less frequent, it would be easier for them to confront with a right-handed opponent in a physical fight; furthermore, left-handers would be also more accustomed to right-handed competitors than vice versa [5]. For all these reasons, some authors [17] justify this advantage by athletes' *reduced perceptual familiarity* with rarely encountered left-handed performance (*negative perceptual frequency effect hypothesis*). For volleyball similar findings were presented; in this case, the actions of left-handed athletes were predicted worse than the right-handed attacks.

The data found in ice hockey [38] support the model of skilled perception and the relationship between laterality and strategic frequency-dependent effects. In relation to training, a study involving handball performance [43] reported once again that left-handers action intentions were predicted worse than right-handed shots. After a training process, the left-hander training group had shown a side specific adaptation pattern, improving prediction accuracy for the left-handed throws (right-hander had shown right side adaptation, improving it for the right-handed throws). Therefore, we think that it might be possible to change or modulate sporting behaviour and improve success linked to laterality training and, thus, to modify the negative frequency-dependent advantage. For example, left-handed players in cricket would have a strategic advantage which would decrease as left-handers become more common in competition, because their opponents (bowlers) would also become more adapted at bowling [37]. Other studies [24] reported that left-handed players were underrepresented in basketball (5.1%); nevertheless they had better performance averages (e.g. number of points or rebounds).

As it was stated, many studies report the relationship between laterality and sporting success, therefore these data should be taken into consideration in the specialization and training of athletes because, based on the negative frequency-dependent selection hypothesis [5, 17, 37, 38, 43, 45], this relationship and the chances of success could be influenced.

Finally, also an excess of mixed-footed players in professional soccer linked to sporting success was reported [4]. However, foot preference seems to be a complex and multifaceted manifestation of lateral preference, and a behavioural index of lateral *functional dominance* [64].

Laterality, success and combat sports

In many sports, specific positions have been designed according to players' laterality (in the sense of *functional dominance*). Thus, in football or handball the different positions of players and the design of the team depended on whether they executed as *right-dominant* or as *left-dominant*. In addition, in fighting sports the design and training of offensive actions (and neutralization actions) against the opponent (fencing, boxing or judo) have been developed based on the opponent's side predominance while executing sporting specific skills.

Among the strategic or interactive sports, the prevalence of left-handers in confrontational sports is even greater if the physical interaction of the opponents is close, such as in judo, where the athletes confront directly; thus, therefore, judo shows a great importance in reference to laterality and success [31, 32, 44, 65-67]. The just cited authors link the laterality of execution to sporting success in judo.

A study [65] involving 750 high level judokas showed that 157 executed symmetrically, i.e. they could execute skills (the same or different) as *right dominant* and as *left-dominant*, and of these 157 (57.3% got a medal). Another study [68], also in international tournaments, showed that the judokas who got a medal had executed on both sides, and used different spatial areas to perform their abilities. Weers [69] analysed the judo duel structure during Olympic Games of Atlanta 1996, and he reported that 48% of the matches presented clearly asymmetric dual structure, being just 10% symmetric duel structure. Dopico [66] also studied the relationship between laterality (in the sense of relative positions and laterality of success techniques) and success in judo (350 successful actions) during the World Championships (Barcelona 1991, Spain), the Olympic Games (Barcelona 1992, Spain), and the World Championships (Chiba 1995, Japan). He showed that in 56% of cases in which a successful attack took place an *asymmetric duel structure* was found, i.e. one right position and one left position; however, the chance of success for a technique executed as *left-dominant* was 68% (32% as right-dominant). Therefore, the *duel structure* was analysed, i.e. the relative positions between athletes when one successful throw took place. It was found that a judo technique performed as a *right-dominant judoka* proved to be more effective against another *right-position* (26%) than against a *left-position* (18%); on the other hand, a technique performed as a *left-dominant judoka* did have a very good chance of being also effective against a *right-position* (38%). In addition, a *right-position* showed a 64% chance of receiving a successful technique, while a *left-position* just 36%. The importance of combat stance in Judo and its relationship with success and sporting level was also shown in other studies [70]. Similar results were found in Mixed Martial Arts (MMA) [71] and in boxing [34] where the southpaw boxers did not win more often than the orthodox ones, but both of them scored more victories when they confronted an orthodox opponent.

Dopico [66] also determined the laterality of 250 judokas (men and women) based on how they executed the sporting judo techniques, that is, regarding their sporting behaviour. The results were 59% *right-dominant judokas, 34% left-dominant,* and 7% others. The highest percentage corresponded to the *right-dominant judokas*, but the percentage of *left-dominant judokas* was much higher than in the general population (no differences were found among gender categories). Support for this view is given by the observation that top judokas with an extremely over-trained action routine tend to be more frequently left- or mixed-handed [6]. Additionally, 24 fights were analysed, in which a bronze medal was competed for. Out of 48 athletes, 56% (34% in playoffs) were *left-dominant* *judokas*, and 44% were *right-dominant judokas*. A bronze medal was won by a *left-dominant judoka* in 67% out of all cases, two *left-dominant judokas* were found in 29.1% of fights, and when one *left-dominant judoka* fought against a *right-dominant*, the victory was for the former in 70% out of all cases. Similar data were found by analysing finals (gold medals). These results show the same conclusions as those found in other studies of similar aged judokas [31, 32] where left-sided athletes had shown significantly better chances of winning medals compared to their right-sided competitors.

In summary, it was discovered that the rate of over-representation of athletes executing judo techniques as *left-dominant judokas* (not necessary left-handed athletes) increased across the level of the competition.

It can be concluded, based on data found so far, that there is some sort of relationship between laterality and sporting success in sports such as judo (namely, an execution as left-dominant or symmetric). Furthermore, it also seems that the relationship between laterality determined by validated and verified tests (hand, foot, eye, ear), i.e., *motoric dominance*, and laterality while executing specific judo techniques, i.e., *functional dominance*, is not strong [47]. In a similar way Loffing et al. [72] had also pointed out that left preference for sport tasks did not necessarily indicate left-handedness. All of this could mean that *functional dominance*, or specific manifestation of executing sport skills, has been acquired (consciously or unconsciously) and, therefore, can be influenced and modified by different learning and/or training methodologies.

We suggest the possibility of a potential *construction of athletes*, specialized in certain movements or sport behaviour from the point of view of functional laterality (sporting execution) and, in this way, the orientation of the *frequency-dependent selection hypothesis*.

Bilateral transfer and sporting techniques

One of the methodologies for training and modifying the sport behaviour regarding laterality is based on bilateral (or interlateral) transfer processes. The bilateral transfer of motor skills is lacking on experimental research, and it is aimed mainly to the determination of transfer processes between dominant and non-dominant sides, above all, using fine motor skills [73-77].

This symmetrization process could also be an important tool to improve sporting techniques that are linked to asymmetric movements execution through contrast and analysis of sensations from both upper, and lower limbs, which would make it possible to clearly recognize the differences and, starting from compensation of such deficiencies, improve the technique of movement. This facilitation of learning by using a symmetric training is based, according to Starosta [78-80], on the bidirectional transfer that takes place during this type of practice, opposite to the unidirectional transfer that occurs in the case of an asymmetric training. As indicated by the same author, the symmetrization process involves a bidirectional flow of stimuli from the nerve centre of a cerebral hemisphere to the other one to produce the most rapid acquisition of new exercises.

If left-handed and right-handed people were able to develop sporting skills in their non-dominant side, it should be considered an advantage in the training process in order to achieve better sport results [81]. Some studies [78] based on symmetric training showed improvements in volleyball shooting (both right hand and left hand) compared to unilateral training of the dominant segment. Also in basketball, where the training which was oriented to overload the work with the non-dominant arm, this training improved bounce and basketball shooting with both hands; similar results in basketball (for a dribbling task) were found by an alternative training for both sides [82], or by training with the dominant hand or with the non-dominant hand [83]. Similar results were found after another training process based on shooting in a different order (one group first with the non-dominant hand, and another group with the dominant hand) in relation to a task which involved throwing the ball to a target [84]. In baseball [85] a bilateral training also confirmed similar yields with both hands in catchers performing a simple task reception. Regarding the lower body, the influence of bilateral practice on lateral asymmetries of performance also was studied in soccer [86]. They found a higher rate of improvement (speed of dribbling) with the non-preferred leg in players who practiced *with emphasis on the non-preferred leg* (after the experimental training), which can indicate the role played by bilateral practice in modifying lateral asymmetries of performance as a consequence of a unilateral training. Also in soccer Witkowski et al. [87] found significant advantages in effectiveness of motor performance with both legs in both experimental groups (E1: ratio of usage of non-dominant/dominant leg was 4:1; E2: ratio was 1:1). Haaland and Holf [88] revealed that the experimental group of soccer players (which practiced increasing the volume of soccer training with the left/non-preferred leg) improved the results with their non-dominant leg as compared to the control group; moreover, they also improved the tests performed with the dominant leg.

In summary, the possibility of symmetrization of sporting motor skills seems to be demonstrated by studies that have found a positive effect of symmetric practice on the acquisition of certain skills; however, most of the studies analyzed self-regulation sporting skills (athletics, gymnastics, etc.) or were held under controlled measurement, even in those studies that focused on external-regulation skills, which usually take place in a context of collaborative-opposition (football, basketball, handball, etc.). In other words, although many of these studies showed interest in knowing the symmetrical training applications and the bilateral transfer possibilities in relation to learning of sporting skills in situational sports (basketball, football, boxing, etc.) the protocols, the measurement tools, the tests and the tasks used were made in closed situations or conditions.

We can conclude that the symmetrization of sporting skills has been verified in situations where the player was not forced to interact with peers and/or adversaries, or in situations where it was easy to assess the motor competence of individuals (i.e., in closed tasks). The previously described research conditions have provided results showing the positive effects of bilateral transfer (as a result of practice with the non-dominant side) but exclusively in self-regulatory situations. In our opinion, these conditions limit the significance of the results, meaning that the coordinative improvement does not ensure the symmetrization of athletes' actions in a real game situation. Therefore, the question arises whether the coordinative improvements obtained in the non-dominant segment through a closed task involves more and better use of that segment in sport real situations [67].

We believe that the usage of motor competence acquired in the non-dominant segment will also require adaptation of the athlete's informational processes regarding the new coordinative resource. In such disciplines as basketball, football, judo, etc., we therefore find it necessary to assess the bilateral transfer processes (symmetrization process) through tasks that require a global motor act (i.e., not exclusively by the intervention of the coordinative processes) to really evaluate the effectiveness of the experimental intervention.

It is likewise necessary to determine whether symmetrization processes tested in simple skills occur similarly in those movements that require precision, speed, and are performed under conditions that vary continuously, as occurs in sport games. Thus, we consider it necessary to assess the effects of different intervention methodologies in contexts that reproduce the conditions of the specific motor interaction in each concrete sport.

Iglesias-Soler [67] showed that laterality of individuals that begin in judo is influenced by the side of execution used in training sessions (non-dominant side training and bilateral training), therefore there is an acquisition component in such lateral dominance; moreover, these training-induced changes are different depending on whether the practice is carried out symmetrically (same volume of executions on both sides), or exclusively by the non-dominant side. Besides, in this study, lateral preference for executing specific judo techniques was affected mainly by the exclusive training on non-dominant side; i.e., left side training implied an increase of judo techniques performed as a left-dominant in a real combat situation. This fact seems to indicate that a young athlete can have some potential for future maturation of sporting motor skills from non-dominant limb in terms of development of more expressive bilateral behaviour [87].

For all the foregoing, and considering the relationship between laterality and sporting success in many sports we consider it necessary to trigger experiences of symmetry in sport initiation, both in opposition situations as in unopposed situations.

Conclusions

The literature review has shown that left-handed athletes are over-represented in sport, and that this over-representation takes place, particularly, in certain sports (confrontational, interactive and, mainly, one against one sports).

The main explanation is that the left-dominant athletes show higher chances of success, especially in these kinds of sports; the main reasons, among others, are because these athletes are less common, hence more unpredictable in competition, and therefore their sporting behaviours (related to laterality or *functional dominance*) are more difficult to *decode* for the opponents, that is, could be an advantage of the strategic type (although *innate* causes have also been proposed).

This strategic fact, and its consequences, have justified the use and the explanation of the frequency-dependent selection hypothesis in sport, i.e., left-handed people are more successful because they are less numerous (negative frequency-dependent selection). Therefore, the *fighting hypothesis* would be based on left-dominant athletes (*functional dominance*) having an advantage when they interact with the right-dominant ones in combat, and particularly in certain fighting sports such as judo.

Our position is that athlete's laterality to execute sport techniques can be changed [67]; that is, it is possible to *modulate* and change the laterality preferences of executing certain motor skills and, therefore, to *create* athletes (from the point of view of the lateral preferences) who are able to perform those motor skills, such as the athlete might need them or as might be required by the coach to be used in competition.

This possibility has also justified the use of the bilateral transfer concept in this paper, since through designing of different training ways based on the effects of bilateral or interlateral transfer processes, the laterality while executing certain sport techniques (i.e., *functional dominance*) could be modified to improve the sporting success.

Finally, this way of training might have some consequences in sport given that, in terms of the frequency-dependent selection hypothesis, the specialization and preparation of certain athletes in particular sports, to take advantage of the laterality in competition, could increase their chances of success; and, therefore, the idea presented in literature of a potential *construction of judokas, boxers, tennis players, soccer players, fencers* (even other athletes) specialized in certain movements, or sport behaviours, and based on *functional dominance* (sportive execution), could also modify the incidence of the results according to the *negative frequency-dependent selection hypothesis*.

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