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Original article

CASE STUDY ON THE DYNAMICS OF CONTROL ASYMMETRY IN ANKLE JOINT EXTENSION MOVEMENT DURING PSYCHO-NEURO-MOTOR CONTROL TRAINING

IACOBINI ALEXANDRA RETA[1, 2, 3], DE HILLERIN PIERRE JOSEPH[4]

Abstract

Aim of the Study. This study presents an analysis based on observations conducted during psycho-neuro-motor control training sessions with junior performance basketball athletes, using the "nautical sports conditions simulator" (hereinafter referred to as the C.S.N. Simulator). The primary aim of the training program was to develop motion control specific to vertical jump performance and to optimize its quality. Although the initial objective of the training did not include symmetry analysis, our observations indicated changes in the symmetry of the lower limbs, as a result of training focused on psycho-neuro-motor control.

Methods. This case study highlights the results of a junior performance basketball player, providing insights into the symmetries and asymmetries that emerged following the application of the training program on the N.S.C. Simulator. The data collected enabled an analysis of the dynamics of symmetry and asymmetry at the level of the ankle joint and calf muscles, offering useful information for improving performance in sports disciplines that require coordinated use of both limbs, depending on the context.

Results. Throughout the study, we observed how the dominance of control in the lower limbs changes based on the speed of movement execution.

Conclusions. Our observations pave the way for further detailed research into the dynamics of symmetry and control asymmetry to identify specific patterns in other exercises and among other basketball players. Additionally, we find it intriguing to extend the research to the upper limbs and to athletes from other sports disciplines. We consider our observations a starting point for future research on optimizing asymmetries in sports to enhance athletes' performance.

Keywords: symmetry, asymmetry, psycho-neuro-motor control, basketball

Introduction

Maloney asserts that humans generally exhibit a predisposition toward one side of the body when performing motor tasks, a phenomenon known as lateralization (Maloney, 2019).

Lateralization refers to the dominance of one of the two cerebral hemispheres, which leads to behavioral inequality between the right and left sides of the human body (Croitoru, 1999). Complementing this concept, Sillamy, in the *Dictionary of Psychology*, states that this dominance is expressed through a preference for using a specific arm, leg, or other body part when performing a motor task. However, this preference is not necessarily consistent across all situations (Sillamy, 1998).

The preference for a specific side of the body (right or left) is commonly encountered in sports, with the choice of the dominant side influenced by both individual preferences and the specifics of the sport practiced (Maloney, 2019). In this context, Castañer emphasizes that athletes' lateralization is a topic of significant interest, as it is closely linked to technical, tactical, and psychological preparation in sports (Castañer, 2018).

The level of asymmetry in an athlete varies depending on the sport practiced and the length of time the athlete has engaged in that sport. Performance athletes typically display greater asymmetries than recreational players (Hart, 2016). In this regard, Maloney suggests that asymmetries can be considered an adaptive consequence that intensifies with long-term athletic training (Maloney, 2019). Lateral asymmetry observed in performance sports is largely determined by the preferential use of one side of the body over the other, especially in complex technical maneuvers, such as shooting a basketball. This asymmetry is often the result of habitual use and technical skills acquired over the course of training (Castañer, 2018).

With respect to lower limb asymmetry in sports, recent research has focused on several types of asymmetries, considering both its direction and magnitude, depending on the skills required in different sports and the tasks to be performed (Arboix-Alió, 2021).

Lower limb asymmetry refers to the dominance of one limb compared to the other, thus influencing performance and functionality (Guan, 2021). Expanding on this theory, Cone highlights that lower limb asymmetry occurs when significant

[1]PhD candidate at the National University of Science and Technology "Politehnica" Bucharest: Corresponding author: alexandra.iacobini@spiruharet.ro;
[2] University Assistant at Spiru Haret University;
[3] National University of Economic Studies Bucharest;
[4] University Professor PhD at the National University of Science and Technology "Politehnica" Bucharest, hillerin@live.com.

differences in strength or power exist between the two limbs. This is particularly evident in bilateral lower body movements. Factors contributing to increased asymmetry include gender, previous injuries to the lower limbs, differences in leg length, and participation in sports that favor the use of a dominant limb (Cone, 2021).

Moreover, team sports often involve unilateral actions performed at high speed, such as jumping, rapid changes in direction, kicking, and throwing, which predominantly engage one limb over the other (Arboix-Alió, 2021). These unilateral movements can contribute to the development of asymmetries between the body sides, significantly impacting an athlete's functional balance and performance. The continuous use of one limb for these actions, such as in shooting or kicking, may disadvantage the other limb, thus accentuating differences in strength and coordination between the two sides of the body (Fort-Vanmeerhaeghe, 2020).

In recent studies on the dynamics of asymmetry relative to movement speed, a significant correlation has been observed between lower limb asymmetry and speed in sports like soccer (Loturco, 2019) and running. Greater asymmetries can negatively impact athletic performance, while running, with its rapid pace, can amplify lower limb asymmetry (Liu, 2022). Additionally, changes in joint mechanics during running may be influenced by the degree of movement symmetry (Healey, 2022). However, it is essential to emphasize that further research is needed to clearly understand how asymmetry and speed interact and how these relationships can be effectively managed to improve athletic performance and prevent injuries. Such studies could contribute to developing more efficient training strategies that address these asymmetries and optimize balance between the lower limbs.

Objectives

The objective of this study is to analyze the dynamics of symmetry and asymmetry during psycho-neuro-motor control training targeting the ankle joint and calf musculature. Additionally, it aims to highlight potential dominance shifts in the lower limbs depending on the execution speed, providing observations that may serve as a foundation for detailed research on reducing asymmetries and enhancing athletic performance.

Methods

This study was conducted through psycho-neuro-motor control training sessions conducted using the "C.S.N. simulator for water sports[5]" (hereafter referred to as the C.S.N. Simulator), employed in our case for its capabilities in adhering to the fundamental principles of simulators. As described by Nicu Alexe, these principles include the creation of measurement conditions[6] and the instantaneous provision of feedback[7].

The case study subject is a member of a competitive basketball team based in Bucharest and a selected athlete for the U16 National Team. The athlete underwent a psycho-neuro-motor development training program focused on enhancing vertical jump ability on the C.S.N. Simulator during a period coinciding with the qualification stages for the National Championship's higher rounds.

Training Protocol

The athlete participated in a five-day consecutive training program on the C.S.N. Simulator, initially aimed at developing control over movements specific to vertical jumping and improving jump quality. Within this framework, an opportunity arose to analyze the patterns associated with the dynamics of lower limb asymmetries during a symmetric movement influenced by the speed of its execution. Thus, the athlete performed an exercise targeting the ankle joint and calf musculature. The exercise involved lying down on the simulator bench with dorsiflexed toes and the simulator cables attached to them. The movement consisted of pushing onto the toes, followed by a vigorous extension of the foot at the ankle joint.

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[5] The C.S.N. simulator is a special device, as described by Angelescu, which has a hardware component (inertial disc, force sensors, electromagnetic braking system, computer) and a software component (Angelescu, 2014, p. 118), which allows, in accordance with the five principles for designing, constructing, and using testing and training equipment, to establish the 'connection' between the athlete and the simulator. Thus, through this system, the athlete can follow a graphical model displayed on the computer screen, with the possibility to control the level of force applied at any moment of a specific movement and in different resistance modes (Angelescu, 2014, p. 118), depending on the established training objectives.

[6] The basic principle, „Creating measurement conditions", refers to the fact that in order to measure various parameters such as force, acceleration, speed, displacement, and time, specific transducers are required to continuously or discontinuously collect information about them (Nicu, 1993).

[7] The basic principle, „Providing instantaneous information", involves equipping the system with the ability to display numerical values, visualize parameter variation curves, provide optical or acoustic warnings, use computers, projection screens, etc. (Nicu, 1993).

Figure 1. Image showing the execution method of the exercise

The control load established for this exercise is relatively low, at 1.5 daN. However, by using a movable pulley that doubles the force load while also providing the athlete with an extended cable length for executing this relatively short movement, the perceived effort experienced by the athlete is equivalent to 3.06 kg-force. It is important to note that the force load is intentionally kept low, as the primary goal of the training is to develop movement control, not to increase strength.

The exercise execution speed progressively increases from one day to the next, following a standard protocol:

- Day 1: The athlete performs 150 repetitions alternating leg movements at a slow speed, with the simulator brake set to 90%.
- Day 2: The exercise transitions to simultaneous movement of both legs, maintaining the same slow speed as the previous day.
- Day 3: The simulator brake is reduced to 50%, requiring the athlete to perform the movements faster in order to maintain control over the predefined movement pattern, thus creating a sensation of acceleration.
- Day 4: The brake is further reduced to 30%, demanding even quicker and more reactive movements compared to the previous day.
- Day 5: The brake remains at 30%, but a motor speed of 0.5 m/s is introduced. The simulator motor ensures a minimum velocity, meaning the athlete does not need to expend effort to achieve it but must generate additional force to exceed this value. This setting places the athlete in a context of higher-speed movement execution, increasing the difficulty and coordination requirements.

To achieve the established task, the athlete uses a reference curve displayed on a monitor as a model to guide their movements. The focus is on the beginning of the movement, which must be quick and controlled, maintaining the motion in line with the predefined model, and completing the movement with an explosive finish.

Real-time visual feedback provides the athlete with information about each execution, encouraging them to make adjustments and correct their movements. This process stimulates the development of efficient motor strategies, enabling the athlete to adapt their movements from one repetition to the next with the goal of closely matching the required model.

Results

In the following section, we analyze observations regarding the dynamics of symmetry and asymmetry identified during the psycho-neuro-motor control training sessions in relation to execution speed, based on the data collected from the training program described above. This analysis aims to provide insight into how speed influences balance and coordination between limbs, contributing to a deeper understanding of motor adaptations in the context of specific training.

1. First training session: alternating work at low speed (90% simulator's brake)

As illustrated in Figure 2, the athlete exhibited minor difficulties in initiating the movement, with the start not being fully controlled in accordance with the imposed model (marked as 1.1. in Figure 2). Additionally, a clear dominance of the right leg (represented by red lines) was observed compared to the left leg (represented by green lines).

This dominance tendency persisted throughout the entire movement, including the plateau phase (noted as 2.1. in Figure 2) and became more pronounced during the final phase of the movement (marked as 3.1. in Figure 3). In this phase, which requires a motor "explosion" on the toes, similar to pushing off the ground during a jump, the right leg's movement control was visibly closer to the required model.

The "explosion" moment for the right leg occurred at approximately 0.20 m, representing 66% of the maximum movement length recorded for this leg, which was 0.30 m. In contrast, the left leg completed its "explosion" earlier, at approximately 0.18 m of its total movement length, representing 60%. Notably, the total movement length of the left leg

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appeared to be greater than that of the right leg. These observations highlight persistent asymmetries in the dynamic movements of the two lower limbs.

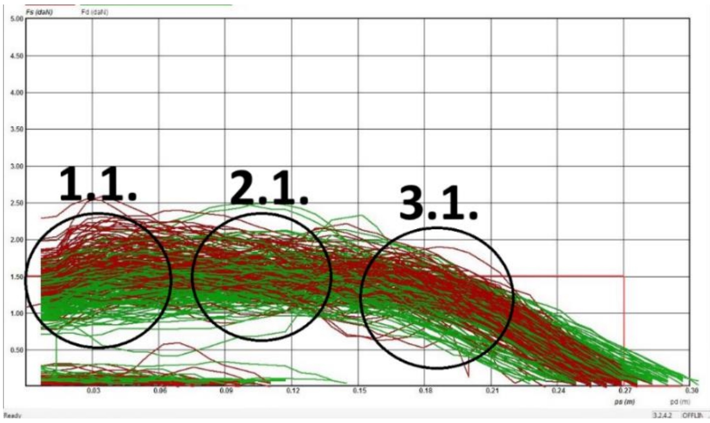

Figure 2. Screenshot of the 150 movements from the first day of training

2. Second training session: simultaneous work at low speed (90% simulator's brake)

In the case of simultaneous work with both legs, a slight improvement in movement control at the initiation phase (marked as 1.2 in Figure 3) can be observed. The execution of both legs aligns more closely with the required control model compared to the previous day. During the plateau phase of the movement (marked as 2.2 in Figure 3), a slight dominance of the right leg is maintained.

However, in the final phase of the movement (marked as 3.2 in Figure 3), the dominance of the right leg becomes more pronounced compared to the alternate work from the previous day. This difference highlights a significant asymmetry in control, with a clear preference for the right leg during the "explosive" phase at the end of the movement.

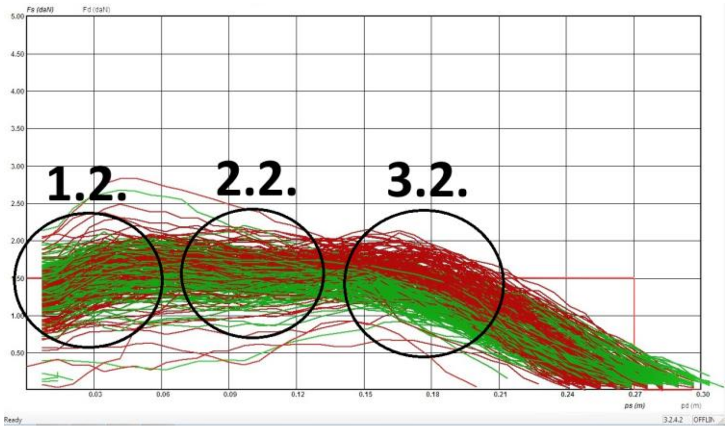

Figure 3. Screenshot of the 150 movements from the second day of training

3. Third training session: simultaneous work with a 50% simulator's brake, offering the athlete a sense of accelerated movement

In Figure 4, an increase in movement amplitude can be observed as a result of reduced braking, which in turn increases the ease of motion. An interesting aspect is the improvement in control with the left leg (green lines) compared to the previous days. This improvement is noticeable both at the beginning of the movement (marked as 1.3 in Figure 4), where the athlete gives the command more quickly, and at the end of the movement, where the "explosive" moment with the left leg is more clearly defined (marked as 3.3 in Figure 4).

During this training session, the athlete manages to control the movement with the left leg up to a distance of approximately 0.21 m, compared to 0.18 m during the first day of training. Although the dominance difference between the executions of the two legs persists, the control asymmetry remains evident, favoring the right leg (red lines). However, this asymmetry is significantly reduced compared to previous days when training was performed at a lower speed. This suggests an improvement in balance and coordination between the lower limbs as the execution speed increases.

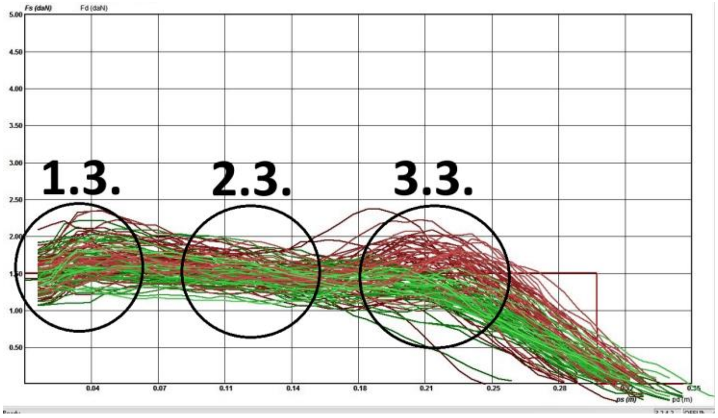

Figure 4. Screenshot of the 150 movements from the third day of training

4. *Fourth training session: simultaneous work with a 30% simulator's brake, offering the athlete an even greater sense of accelerated movement*

Figure 5 shows that the movement length for both legs remain increased, similar to the previous day, and the control begins to become symmetrical between the executions of the two legs. The difference between the two colors (representing the right and left legs) starts to decrease significantly, with no clear distinction between their executions. This is evident at the start of the movement (marked as 1.4 in Figure 5), during the plateau phase of the movement (marked as 2.4 in Figure 5), and especially at the end of the movement (marked as 3.4 in Figure 5).

In previous days, a pronounced control asymmetry was observed at this final point, suggesting a significant improvement in balance and symmetry between the two lower limbs.

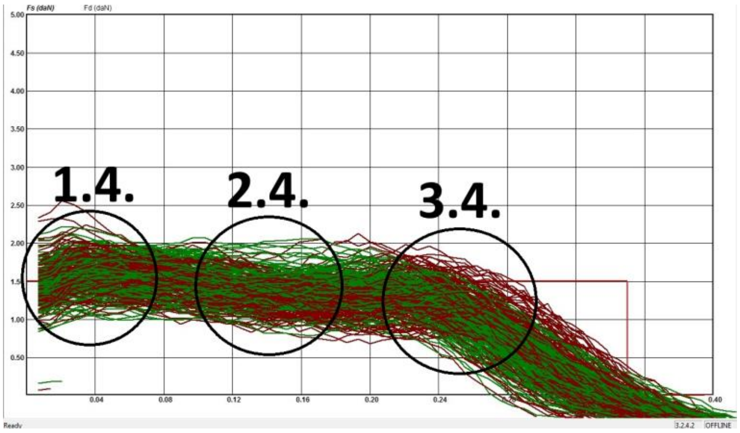

Figure 5. Screenshot of the 150 movements from the fourth day of training

5. Fifth training session: simultaneous work with a 30% simulator's brake and a motor speed of 0.5 m/s, offering the athlete an even greater sense of accelerated movement compared to the previous day

From the start of the movement (marked as 1.5 in Figure 6), it is evident that the athlete struggles to issue a sufficiently rapid command to initiate the movement at this speed, failing to achieve the control task set at 1.5 daN. As a result, the athlete manages to control the movement only after approximately 0.12 m of total movement length, and the plateau phase is also poorly controlled (marked as 2.5 in Figure 6).

The most intriguing and significant aspect, which opened the opportunity for further investigation, occurs in the final phase of the movement (marked as 3.5 in Figure 6). A radical change in control is observed in the execution of the dominant leg. During the first three training days, the right leg was clearly dominant (represented by red lines). However, as speed increased, the left leg became dominant during the "explosive" phase at the end of the movement.

This change raised our curiosity about whether such a pattern is also present in other exercises performed by the athlete during training and, potentially, among other basketball players or athletes from different sports disciplines.

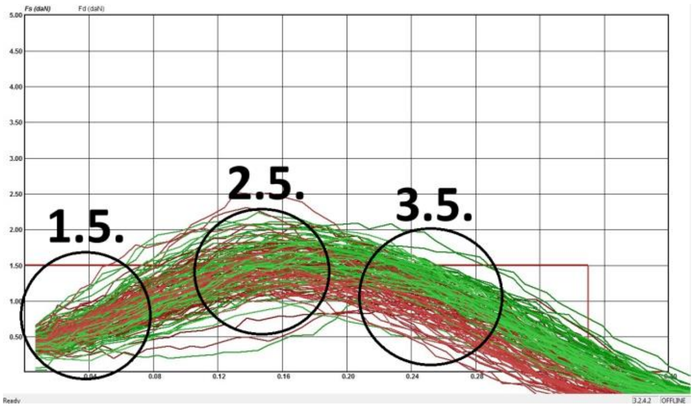

Figure 6. Screenshot of the 150 movements from the fifth day of training

To provide an overview of the dynamics of the athlete's symmetry and asymmetry, a graph was created to highlight the athlete's executions during symmetric training sessions. This graph reflects the athlete's progress in movement control over the four days of symmetric work, illustrating both moments of asymmetry and tendencies toward symmetry in their executions. By analyzing this data, we can observe the athlete's evolving ability to control symmetric movements and reduce differences between the two legs as the execution speed increases. The graph provides a clear depiction of how the dynamics of symmetry and asymmetry change over time and can serve as a useful tool for adjusting the training program.

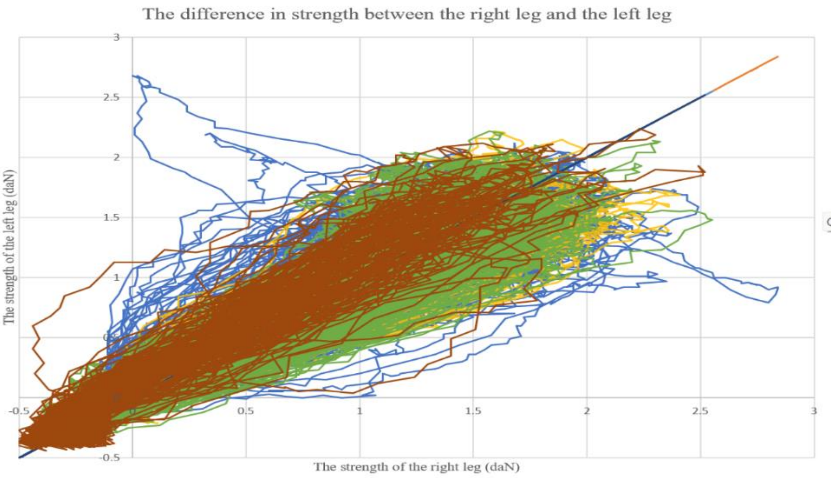

Figure 7. Symmetry dynamics across the four symmetric training sessions

Figure 7 presents the force differences between the executions of the two lower limbs during the symmetric training sessions. Each training session is represented by a specific color corresponding to a particular combination of speed and braking:

- Blue: Second training session (simultaneous execution at low speed – 90% simulator's brake).
- Yellow: Third training session (simultaneous execution with a slight increase in speed – 50% simulator's brake).
- Green: Fourth training session (simultaneous execution at higher speed – 30% simulator's brake).
- Red: Fifth training session (simultaneous execution at high speed – 30% simulator's brake and motor speed of 0.5 m/s).

The graph plots the right leg's force on the OY axis (in daN) compared to the left leg's force on the OX axis, with the right leg serving as the reference point.

As seen in the graph, the dominance in the control of lower limb movements changes based on the speed of execution. At low-speed executions (second training session), the athlete demonstrates "right-side dominance." Conversely, at higher-speed executions (fourth and fifth training sessions), the dominance shifts to the left leg. This change in dominance reflects the adjustments in control and the athlete's adaptation to the speed demands of more advanced training.

Conclusions

Following the analysis of the athlete's asymmetry dynamics, we explored potential explanations for the change in dominant leg depending on the speed of execution. One hypothesis may relate to the athlete being right-handed, with the right hand being the more dexterous limb. In this context, it is possible that during jumps, the athlete frequently uses the leg opposite the dominant hand (in this case, the left leg), explaining why it becomes dominant during high-speed executions. Thus, rapid and dynamic movements are executed with the left leg, as the athlete is more comfortable relying on the leg corresponding to their "non-dominant" hand. Conversely, for slower, strength-based movements, which may be associated with defensive actions, the right leg becomes dominant. This is likely due to better control and greater stability on the right leg during heavier, slower movements. Nonetheless, an interesting objective would be for the athlete to develop enhanced and balanced control over both limbs, regardless of execution speed. This would represent a challenge for in-depth research into these asymmetry dynamics, considering that the athlete, due to their experience and physiological characteristics, tends to rely more on one leg or the other depending on the type of movement performed.

In conclusion, this study demonstrated how control asymmetry, which should ideally be absent in symmetric movements, was observed throughout the training period. Moreover, this asymmetry varied depending on the speed of movement execution. Additionally, it was observed that as the execution speed increased, the quality of movement control significantly declined, with the athlete beginning to perform "ballistic" movements, often uncontrolled. This suggests that the motor speed set may have exceeded the athlete's control capacity, leading to a loss of precision in execution. These observations open the path for more detailed research into the dynamics of symmetry and asymmetry to identify patterns in other exercises and, potentially, among other athletes in basketball and other sports disciplines. We also find it intriguing to extend this research to upper limbs and athletes in other sports fields. Our observations serve as a starting point for future research focused on optimizing asymmetries in sports to enhance athlete performance.

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