2.2 Interrelation of muscle actions in movement and maintaining a position

The different types of muscular action have been presented in the previous unit, along with the SSC, to which we could refer as the minimum unit of movement in the sport. In this unit, we will focus on understanding the musculature from a functional point of view.

In the first topic, we will deal with the concepts of tonic and phasic muscles, which are essential to understanding why there are certain muscles with different levels of speed and endurance, as well as the concepts of monoarticular and biarticular muscles, with an anatomical meaning that is also related to functionality.

2.2.1 Tonic and phasic muscles

In general, the literature defines tonic muscles as those with a greater connection to maintaining posture. These are organs that are primarily composed of Type I muscle fibers, innervated by motor neurons with slow neural conduction and with an organized intrafusal system, in order to maintain the tone necessary to achieve a permanent balance. It should be noted that Type I fibers possess limited glycolytic activity, although, on the contrary, due to their high mitochondrial density and capillarity, they express a high resistance to fatigue (Wilmore and Costill, 2007).

The concept that Philippe Souchard refers to with regard to tonic muscles allows us to understand their functionality, as this author describes these as being continuously active, in order to maintain their constant tonality and to avoid losing the desired posture. The author also explains that these muscles, constantly activated to avoid a loss of balance, will try, by all means, to bring their insertions closer. That is, they will shorten; reflecting what actually occurs in reality (Souchard, 2008). With this in mind, it is easy to understand why these types of muscles tend to suffer from shortening, which hinders their nutrition and their extensibility and elasticity abilities. In a study carried out by this same author (Souchard, 1996), more closely related to the sport, he suggests examining the role that tonic muscles can have in sporting actions. In this regard, the author explains that these muscles, which tend to shorten, can create a problem in which the muscle system, characterized by performing actions at high speed, is limited. That is, to be able to execute highly explosive movements, we should preserve the property of elasticity of these antigravitational muscles. According to this reasoning, we should apply

the type of global stretching that this author proposes. However, we can also program the type of exercises related to strength training in this course, and which have a compensatory or preparatory orientation of more functional exercises, related to sports skills.

We must take note that the training load tends to be excessive in certain contexts, which makes it difficult for the athlete to recover. The tonic musculature is included in this recovery, and this can react with greater tension to what we could describe as a certain aggression. If this continues and the necessary measures to mitigate this effect (preservation of extensibility and elasticity) are not carried out, then there is a greater reaction towards increased tension and shortening, which may lead to the musculoskeletal disorders that are so common among athletes. These are usually interpreted as normal situations as part of the training load, due to the fact that they do not interrupt the athlete's activity, at least in the short and medium term. Reflecting on this, although it is not part of this topic, we must ask ourselves whether these actions signal a potential decrease in sporting performance. In addition, according to Kwon, Choi, Yi and Kwon (1998), we must take into account that the tonic muscles can be affected by the temporary increase in temperature triggered by exercise, which causes a decrease in the stimulation of the secondary endings of the neuromuscular spindle. This decrease can be considered a proprioceptive alteration that leads to a decrease in the tonic response of the muscle, which is related to the ability to maintain a posture. These authors explain that muscle fatigue around a joint can inhibit the proprioceptive information needed to regulate a position.

On the other hand, phasic muscles are defined by characteristics inconsistent with tonic muscles. It is a musculature that expresses itself through movement; usually located in the extremities, primarily composed of Type II muscle fibers, and a preferential neural connection of rapid neural conduction by means of alpha-phase motor neurons. On the inside of the neuromuscular spindle, these fibers are connected to dynamic gamma motor neurons. Type II fibers, as was explained in the previous module, are characterized by a high capacity to generate tension at high speed, with high glycolytic activity and poor mitochondrial density. A greater amount of this type of fiber in a muscle is what defines it as phasic, which has a high capacity to develop explosive actions but a low resistance to fatigue (Wilmore and Costill, 2007).

Phasic muscle, as opposed to tonic, tends to experience flaccidity when not sufficiently used; that is, when it is inhibited (Souchard, 1996). This results in a completely different approach to the tonic muscles, with the intention of preserving the health of these "fast" muscles. The objective is to find an optimal way to keep these muscles active, with more punctual and appropriate stimuli to facilitate their recovery, so that they can exercise

without limitations, and with the acceleration and speed required by sports skills.

Likewise, if we try to relate tonic and phasic muscles to the joint movement amplitude presented in module 1, it could be said that in general terms tonic muscles alteration can be corrected by performing Total Amplitude, External Amplitude workouts and eccentric tensions. Meanwhile phasic muscles alterations could be corrected by using Medial Amplitude and Internal Amplitude workouts, and concentric tensions. (Cos and Porta 1998). This does not mean that eccentric tensions have to be avoided for phasic muscles, but the intension is to present different tools for every type of dysfunction.

Despite this traditional classification, which is used for didactic reasons, it is necessary to understand that, in reality, all muscles have dynamic and static requirements. This is especially true for sports activities. Although the work of Comerford and Mottram (2001) is more clinically inclined, the functional classification made of the skeletal musculature is truly interesting, from the perspective of injury prevention and sports performance optimization. These muscles are then divided as follows: local stabilizer muscles, global stabilizer muscles, and global mobilizer muscles. The alteration of the local stabilizer muscles is produced by a modification of motor recruitment, which can lead to a loss of segmental control, as explained in the works of Paul Hodges and Carolyn Richardson (Richardson, Jull, Hodges and Hides, 1999).

As for the dysfunction of the global stabilizer muscles, this is caused by an increase in functional muscle length or by a decrease in the recruitment of motor units with a low threshold of excitability (Gossman, Sahrmann and Rose, 1982, in Comerford and Mottram, 2001). Finally, the alteration of the global mobilizer muscles is caused by a loss of muscle extensibility or by overactivity of motor units with a low excitability threshold. These events trigger global alterations of the muscular balance, and the link between flexibility and stiffness is altered around the segments. As we have previously mentioned, although this classification is limited to the clinical field, it helps us to understand the process by which tonic muscles can cause alterations in the muscles that generate movements made with high acceleration and speed. In this regard, Gantar (2016), quoting Page, Frank and Lardner (2010), describe how the tonic and phasic muscle systems do not function individually or in isolation, but jointly intervene through coactivation; in order to maintain a position and, in general, to initiate and carry out a coordinated movement. It is this interaction that allows the joint to focus on a specific action, and allows for a balance of muscular forces that maintain joint congruency during a skill. It is important to link this

occurrence with the concept of neuromuscular control, as seen in this course; specifically in course two, focused on training.

The alteration of neuromuscular control is expressed through the existence of movements that we can describe as "uncontrolled". This term is used by Buckthorpe, Gimpel, Wright, Sturdy and Stride (2018) in a study on the prevention of hamstring muscle injuries, especially when this lack of movement control is concentrated in the Lumbo Pelvic Hip Complex. Based on the approach to intervention suggested for professionals, they consider the training dichotomy between the following: the efficacy of local stabilizer muscles, which are tonic, according to the aforementioned classification, and therefore have a distinct function in postural control; and the global stabilizer muscles, in which fast motor units prevail and which possess phasic characteristics, upon generating high forces to perform rapid actions. In this study, the lack of control of the anterior pelvic tilt during a sprint is provided as an example, as this can cause significant stretching of the hamstring muscles, and lead to an increase in tension of the long side of the femoral biceps at the end of the oscillation stage of a stride. In this regard, the excessive tension of the hip flexors has been identified as a risk of injury to the hamstring muscles. It is also associated with a pelvic tilt in a sprint, which causes an increase in tension in the same stage of the stride. In addition to the increased tension of the hip flexors, the gluteus maximus is inhibited by reciprocal inhibition, resulting in a synergistic dominance of the hamstrings.

2.2.2 Monoarticular and biarticular muscles

From a conceptual point of view, monoarticular muscles are those that act in isolation in one joint, while biarticular muscles do so in two different joints. We can mention polyarticular muscles, but we typically refer to "polyarticular exercises" to specify the inclusion of multiple joints in an exercise (Cos, Porta and Carreras, 2011).

Biarticular muscles have been recognized as being a risk factor for injury. In particular, this factor is related to hamstring injuries (Woods, et al., 2004); muscles that are recruited from the hip and knee in typically explosive actions. In this last study, the authors add the potential imbalance of coordination patterns to the anatomy of these muscles. They argue that hamstring muscles, if exercised in a predominantly tonic way, might not withstand the potentially harmful loads of highly explosive actions. In the previous topic, when discussing tonic and phasic muscles, we linked potential muscular alterations with different types of imbalances. The aim of this topic is not to focus on hamstring injuries, but it is important to note that these biarticular muscles represent the greatest risk of injury in sports such

as soccer. If the training is not designed to trigger the necessary adaptations for this type of muscle, which carries out repetitive explosive actions, an injury can easily happen when such muscles are recruited under these conditions.

We can highlight the theory developed by Prilutsky (2000) on the relationship between monoarticular and biarticular muscles in polyarticular exercises, which makes it possible to identify the characteristics of muscular coordination in movement. In this regard, the author established a conceptual model of **motoneuronal connections between these muscle groups**, which led him to affirm that exercises with a high level of learning show stereotyped behavior. The author theorizes about how to achieve this stereotyped movement through learning, and supports this by explaining that the biarticular muscles have a maximum impact when they are recruited as agonists in the two joints that they cross. There is a medium level of activation when they are agonist in one and antagonist in the other, with less activation when they appear as antagonist in both, although this is true only for static conditions. On the other hand, in the dynamic actions, this essentially complicates the modifications that occur within the changes in elongation and the speed with which they occur. A higher level of activation is located in the muscles that can produce a greater action with less effort, as expressed by the biarticular muscles; compared to monoarticular or biarticular muscles, which play an antagonistic role in one of the two joints that are related. That is, in order to carry out a movement, the NS has a preference for using a biarticular muscle, rather than the activation of two monoarticular muscles that could perform the same action, since this has proven to be a more advantageous option, according to the author.

The development of a motor pattern that follows this model has the following advantage, in terms of intermuscular coordination: it attempts to reduce muscle fatigue, saves energy and facilitates the transfer of mechanical energy between joints. In terms of this last aspect, the proximal muscles of the lower limb have a larger volume, and therefore a greater capacity for mechanical exercise, compared to the distal muscles. This means that the proximal muscles can compensate for the limitation of the distal muscles, and this action can be carried out by the biarticular muscles that distribute mechanical energy between the proximal and distal joints (here, we cite Prilutsky, Herzog and Leonard, 1996 and Prilutsky and Zatsiorsky, 1994).

After having discussed the foundation of the neuromusculoskeletal system, examining the functions of the monoarticular and biarticular muscles will lead us to the concept of coordination. Despite the discussion on the role of these muscles, Kautz, Neptune and Zajac (2000) have a different reasoning than Prilutsky (2000), in terms of explaining why a certain coordination between muscles takes place. In this regard, the work of Kautz, et al. (2000)

is based on an analysis of movement more closely linked to dynamic reality (connecting the kinematic and kinetic aspects of an exercise). In this regard, the critique made by these authors of Prilutsky's theory is based on the fact that the former describes muscular forces; that is, how the different muscles must organize in order to obtain force. On the other hand, explaining neuromuscular coordination is much more complex, and for this reason, it is necessary to understand why the NS produces a certain muscular activation that leads to a number of joint movements in an exercise. In fact, as we have seen, one of the main aspects that explains motor organization, according to Prilutsky, is efficiency in relation to effort. However, this cannot explain sports actions, where the outcome of the action and its effectiveness is more relevant than saving energy, when we refer to specific skills in team sports.

In this regard, when playing sports, the neuromuscular system organizes itself in order to meet the demands of the different situations, which often occur with a significant time constraint. This idea is supported in the writings of Kautz et al. (2000), which explain that the principles that can regulate coordination can only be identified if we understand the process, in which the set of muscular forces that are involved in an action are successfully performed.

For years, intermuscular coordination has been studied in actions that can be controlled from a kinematic and dynamic point of view, but this study becomes complicated when the actions to be studied are highly complex, such as sports skills performed at high accelerations and speeds.

Research has been conducted in an attempt to clarify the relationship that is established between monoarticular and biarticular muscles in a movement. Jankowska (1992), who analyzed the act of lifting a weight (which is well-studied within ergonomics and can be compared to a squat in sports), explains that the reciprocal coordination between monoarticular agonists (soleus, in relation to the tibialis anterior) and biarticular agonists (rectus femoris, in relation to the hamstring muscles) is controlled peripherally by the muscular inputs, which capture the variation in muscle length and the degree of tension generated. A distal to proximal sequence of the different articular rotations involved was recorded in this lifting action (Burgess-Limerick, Abernethy, Neal and Kippers (1995), which could be a result of keeping the biarticular muscles close to their optimal length for as long as possible in the action. Fatigue can alter this sequencing of muscle activation, which would cause a change in optimal length, and thus a decrease in the efficiency of the action.

In relation to this lifting exercise, Prilutsky, Isaka, Albrecht and Gregor (1998) used electromyography to study the relationship between biarticular muscles (gastrocnemius, hamstring and rectus femoris), as well as the moments generated in the ankle, knee and hip. In this analysis, the authors linked the coordination of the biarticular muscles to the attempt to trigger a

minimum amount of fatigue, since these muscles can develop the necessary articular moments with less effort. Cheron, Bengoetxea and Draye (1998) recorded how a squat, a movement that is typically analyzed in sports, was organized around the knee; highlighting the importance of the biarticular muscles in the transmission of articular moments produced. Among the different coordination strategies in the action of lifting, the activation of the monoarticular musculature is invariable, while the biarticular musculature has a varied activation model.

Despite the analysis of this action, and based on the studies analyzed, we should arrive at the same conclusion: we cannot compare the kinematic and dynamic analysis of an isolated action, nor a cyclical one (without a disturbance), with the analysis that we must carry out on sports skills. For this reason, to discuss coordination with the objective of "efficiency" means we do not know the true objective of a sporting action in competition, where the effectiveness of the skill is sought more than any other objective, including the aim of protecting oneself from injury.

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