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CURRENT OPINION

Muscle Madness and Making a Case for Muscle-Specific Classification Systems: A Leap from Tissue Injury to Organ Injury and System Dysfunction

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Abstract

Despite the recent publication and subsequent clinical application of several muscle injury classification systems, none has been able to address the varying and often unique/complex types of injuries that occur in different muscles. Although there are advantages of using a unified classification, there are significant differences between certain muscles and muscle groups. These differences may complicate the clinical effectiveness of using a unified injury classification. This narrative explores the difficulties in using a single classification to describe the heterogeneous nature of muscle injuries. Within that context, the possibility of viewing muscles and muscle injuries in the same manner as other biological tissues, structures, organs, and systems is discussed. Perhaps, in addition to a unified classification, subclassifications or muscle specific classifications should be considered for certain muscles. Having a more specific (granular) approach to some of the more commonly injured muscles may prove beneficial for more accurately and effectively diagnosing and treating muscle injuries. Ideally, this will also lead to more accurate determination of the prognosis of specific muscle injuries.

Key Points

It is common in our daily practice to have difficulties in using a single classification system when assessing muscle injuries.

If a unified nomenclature and approach cannot be applied the multidisciplinary and individualized management of muscle injuries is much more difficult.

While general muscle injury classifications that reflect a common nomenclature can be used, subclassifications that address the idiosyncrasies of each muscle's local tissue structural architecture and anatomy for the most frequently injured muscles should also be considered.

1 Introduction

In our daily practice, when evaluating muscle injuries, it is common to have difficulties using a single classification system. The liver and spleen, for example, have different

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classifications systems for traumatic injuries. The long and short bones also have different classification systems for fractures. Finally, the shoulder and ankle have different classification systems for dislocations. So, despite the variability in muscle structure and function, why are all muscle injuries grouped into a single global muscle injury classification system?

2 Are All Muscles Created Equal?

Over the past few years, there has been a renewed interest in the classification of muscle injuries. The traditional three grade system that has been in use for many years has proven to have shortcomings. This system has a three-grade clinical or imaging grading score [1] as follows: grade I (stretch injury): a small tear resulting in less than 5% of fiber disruption; grade II (partial tear): a larger tear with 5–50% of fiber disruption and decreased strength; grade III (complete rupture): greater than 50% or complete fiber disruption and loss of strength/function. This general classification scheme has been applied using clinical [2, 3], ultrasound [1, 4] and MRI points of view [1, 5].

The shortcomings of the three-grade system are most evident in the diagnosis and management of muscle injuries in elite athletes. In fact, in the past 8 years, at least four new classification schemes have been published [6–9]. These more recent schemes are a positive step forward in the effort to better classify and grade muscle injuries. In addition, they have facilitated more targeted research, specifically by allowing better delineation of the location of lesions and allowing the use of more uniform nomenclature. Despite certain similarities and differences between them, all the classification schemes aimed to be practical and, to a certain extent, provide prognostic information regarding muscle injuries [10].

The consensus statements from Munich [7], Barcelona [9] and the British Athletics Association [8] all agree that MR-negative muscle injuries have a better outcome than MRI-positive muscle injuries. However, they all appear to have limitations in determining the exact contributions of imaging studies in an objective and reproducible manner [11–13].

The validity or reliability of the system proposed by Chan [6] or the Barcelona system have not yet been demonstrated [9, 14]. The Munich consensus statement [7] showed a broad range of RTP (return to play), especially for minor partial, moderate and subtotal tears; therefore, it may have limited value from a prognostic perspective. Pollock et al. [8] have not been able to demonstrate a clear difference in prognosis between grade 1 (small tear) and grade 2 (moderate tear) injuries, or between myotendinous and myofascial junction injuries. Grade 3 (extensive tear) muscle injuries and intra-tendinous injuries had a worse prognosis than all other grades. However, no other characteristics could discriminate the interval to RTP [15].

As discussed by Hamilton et al. [10], since the beginning of the twenty-first century, published studies with large cohorts have been used to evaluate the prognostic validity of clinical and imaging observations. In most cases, the length, cross-sectional area, and estimated volume of the muscle injury have been evaluated using MRI to propose indicators of the severity of the injury and guide a rehabilitation period [11, 12, 16, 17]. Only one study has highlighted that, in addition to any of the radiological characteristics described above, intramuscular tendon damage may be the most relevant predictor of the duration of RTP. Ultimately, most of these studies are limited by the fact that their prognostic indicators still require clinical validation [10].

One similarity and, in our opinion, limitation of all these schemes is that they intend to provide a global classification system for use in any muscle in the human body. These classifications do not consider significant differences in the architecture, composition, and function of different muscles (and muscle groups) in the body. For instance, consider the variability with regards to being mono- or biarticular, the presence or absence of free tendons, multiple tendons, conjoint tendons, intra-muscular tendons, unipennate and/or bipennate configurations (including their coexistence in a single muscle) [18–20]. Thus, an injury to the proximal tendon of the adductor longus may not have the same configuration or prognosis as an injury to the proximal tendon of the semitendinosus. An injury to the intra-muscular portion of the tendon of the rectus femoris may not have the same configuration or prognosis as an injury to the intramuscular portion of the tendon of the soleus. For that reason, it may be useful to have muscle-specific classification systems that accurately reflect the variability in anatomy and architecture of certain muscles.

3 Biological, Structural and Systemic Approach to Muscles

In biology, the organizational approach to anatomy is well-recognized [20]. A tissue is a collection of specific types of cells that are organized with similar structural (and functional) characteristics to carry out a specific function/purpose. Embryologically, in the human body, there are four main types of tissues: epithelium, connective tissue, muscle tissue, and nerve tissue [20]. Each of these tissues has specific differentiations related to the specialization of its intracellular elements and extracellular matrix [20]. When cells and tissues come together into well-differentiated structures to carry out a specific function, they are called organs.

Although two organs can be made of similar tissues, these organs can be quite different due to the subtypes of the constituent tissues. For example, consider the liver and the pancreas. Both are made up of epithelial tissue, connective tissue, and nervous tissues. However, the differences in the subtypes of epithelial (glandular) tissues result in markedly different morphology and function [21]. The same could be the case in muscles. When we compare the soleus and rectus femoris, although both are made of muscle tissue, connective tissue, and nerve tissue, the specialization and sub-specialization of each muscle (both are skeletal muscles) results in completely different morphology, structure and function [22].

It is not only the sub-specialization of tissues that determines organ function. The function (or functions) of an organ is (are) also dependent on the actual structural architecture of the connective tissues as well as the communication between nervous tissues [21, 23]. For instance, the adductor longus and the rectus femoris could be considered different types of organs given that, in addition to one being monoarticular and the other biarticular and having different ratios of muscle fiber types, the organization and distribution of the connective tissues result in significant differences in their morphology, spatial orientation, and fixation to adjacent bones. All these factors affect their function as well. So, at the organ level, these two muscles seem to have similar function a priori: to move a joint in various planes. However, architecturally, they are quite dissimilar with marked differences in their attachments to bones, the number, configuration, and orientation of their tendons, and the various components and configurations of their connective tissue matrix.

What happens when we ascend yet another level in the biological organization approach? A group of organs that performs common (and possibly complex) functions is called a system. The function or functions of a system is/are much more than merely the summation of the function of each individual organ in that system. Using the previous example, although the main function of the adductor longus is adduction of the hip (in the coronal plane), it plays a much more complex multiplanar role as it also contributes to hip flexion and hip external rotation. When combined and coordinated with the actions of the other pelvic and lower extremity muscles (organs), it acts not only to adduct the hip but also to stabilize and properly orient the hip during complex activities, thereby contributing to the system. The same can be said of the rectus femoris muscle. As an "organ" it acts to extend the knee and, to a lesser degree, flex the hip (both in the sagittal plane). However, when combined with the other "organs" of the skeletal system—bones, joints, muscles—from the spine to the feet, it forms part of a system that acts to stabilize and properly orient the knee in other complex activities [24]. As such, the adductor longus and rectus femoris have many similarities at the organ level but may have differences regarding their roles within the system.

4 New Perspectives on Muscle Injuries

Returning to a practical and clinical application of the above peculiarities of different muscles, perhaps muscle injuries should not merely be thought of as a local tissue injury but instead thought of as organ injuries. In addition, these organ injuries should always be evaluated and classified in the context of their contribution to the relevant system. Classification systems would be most clinically relevant if they reflected the anatomical and functional roles of muscles as organs within a system, offered a common nomenclature, and contained subclassifications for the most commonly injured and clinically problematic muscles.

Perhaps muscle injury classifications should be similar to classifications that take into account specific cell types, specific organ injuries, and specific system dysfunctions. Global and nonspecific muscle injury classifications may not be ideal, particularly when considering that the closely related skeletal system has very specific classifications for specific common bone and joint injuries.

Consider the closely related Association of Osteosynthesis (AO) classification for fractures [25]. The AO classification unifies fractures in terms of description and subsequent data management. However, there are subclassifications, taxonomically differentiating long bones from short bones and further subclassifications of long bones of the upper and lower extremity. The AO group used the comprehensive classification of fractures of the long bones and divided them into types, groups, and subgroups [26]. There is even a subclassification for the different segments of each limb (one bone or two bones) [25]. Likewise, due to their different mechanical behavior, there are subclassifications for short bones (e.g. patella) [27, 28] or certain intra-articular fractures (i.e. ankle [29] or distal radius [30]). The goal of these subclassifications is an attempt to provide greater specificity and, ultimately, greater clinical relevance. As is evident, the AO system considers each bone to be a specific organ. However, to date, the classification systems for muscle injuries have been meant to be applicable to all muscles. None of the existing muscle classifications take into consideration the significant variability in the structure and function of different muscles, including significant differences at tissue, organ and system levels. For these reasons, perhaps general muscle classification systems should have subclassifications for the most frequently injured muscles.

5 Muscle-Specific Classifications for the Most Common Injuries

Having a single muscle injury classification system that intends to describe all muscle injuries appears to have limited benefit in facilitating communication between health professionals. In fact, given the wide variability in muscle anatomy, using such a unified classification may at times impede clear and concise communication. For that reason, our proposal is that there should be muscle-specific classification systems (or subclassifications) for the most commonly injured muscles or muscle groups. This would be similar to fracture classifications where specific classification systems exist for a few specific commonly injured and functionally important bones. The majority of indirect muscle injuries are limited to a few muscles and muscle groups such as the hamstrings, the rectus femoris, the triceps surae (particularly the soleus and the medial head of the gastrocnemius), and the adductor longus. Although other muscles can also be injured by an indirect mechanism (e.g. pectoralis major, pectineus, etc.), the previously mentioned most commonly injured muscles are those that may benefit from having their own subclassification within a global classification, thereby reflecting their precise anatomy, function and prognosis.

Perhaps muscle-specific classification systems -or subclassifications within a global classification- should consider muscles or muscle groups as organs, each with its unique complex anatomy. These classifications should also describe muscle injuries taking into account the concept of the regional system, and thus provide more effective communication between health professionals. These may then be modified or adapted (i.e. through targeted research projects) to account for differences between sports, positions, individual players, or even dominant versus non-dominant limb injuries in certain instances. Such detailed subclassifications should allow more specific and individualized diagnosis, categorization, and management of muscle injuries. Such a detailed and specific classification system may provide better prognostic information which, after all, is the Holy Grail of managing muscle injuries.

6 Conclusions

In summary, our proposition is:

- Thinking of muscles as organs, considering the various tissues and subtypes of tissues involved.
- Thinking of muscles in the context of their regional system.
- Using general classifications that reflect a common nomenclature but also using subclassifications that address the idiosyncrasies of each muscle's local tissue structural architecture and organ-level anatomy for the most frequently injured muscles: hamstrings, triceps surae, rectus femoris and adductor longus.

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