International Journal of Science and Healthcare Research
Vol.7; Issue: 3; July-Sept. 2022
Website: ijshr.com
Review Article *ISSN: 2455-7587*

Neglected Mechanical Basis of Skeletal Muscle Stretch: Dichotomous Biomechanical Insights

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DOI: https://doi.org/10.52403/ijshr.20220722

ABSTRACT

Optimally flexible muscles support ideal postures, basic movements of Activities of Daily Living (ADL) and advanced skills of Exercise, Sports and Occupation. But flexibility of muscles usually gets diminished due to lack of exercise, adaptation of incorrect postures, and restricted mobility caused by injuries, diseases and ageing. Inflexibility of muscles in turn could cause unpredictable deterioration of functional capabilities. Inflexible muscles have the potency to impair the neuromuscular coordination and mechanical efficiency of ADL, Squats, Lunges, Forward bending, Single leg balance, Locomotion and athletic traits that are usually evident in thorough fitness evaluations. Stretch postures can be used in clinical diagnosis, prophylactic regimens and therapeutics. Stretching exercises have been an inevitable component in structured physical activity for general health, maximizing exercise performance and various disease rehabilitation. Maintenance of full range of motion of all the moveable axial and appendicular joints ensures adequate exposure of the neuromusculoskeletal system to gravitational forces, and help preventing the debilitating effects of Gravitational Torque Deficiency Syndrome. Though plenty of explanations and evidences already exists to understand and apply stretch science, one important 'biomechanical fundamental' has been found neglected. This article aims at concisely explaining that 'neglected biomechanical fundamental' of stretch biomechanics with the help of logical reasoning and innovative illustrations. Keeping these innovative biomechanical interpretations as a foundation, it is possible to elicit comprehensive research pursuits among Exercise Professionals to explore stretch mechanics of all the skeletal muscles at an arthrokinematic level, and upgrade the standards of stretching exercise prescriptions.

Keywords: Flexibility, Inflexibility, Stretching Exercise, Range of Motion, Stretch Biomechanics, Muscle Tightness, Subluxation, Arthrokinematics

INTRODUCTION

Maintaining full range of motion in all the joints is one of the key determinants of healthy ageing. Optimally flexible muscles support ideal postures, basic movements of Activities of Daily Living (ADL) and advanced skills of the Exercise, Sports and Occupation. Abnormal deviations from optimal extensibility contribute to muscle imbalances, faulty posture and dysfunctional movement. Physiotherapists and Medical professionals from various disciplines are aware of the advantages of stretching exercises for; maximizing exercise/sports/occupational performance, healthy ageing, postural/movement dysfunctions caused by sedentary lifestyle, debilitating illnesses, contractures, joint stiffness, etc., "Due to their analgesic properties, stretches might relieve discomfort and break the cycle of discomfort-pain-muscle stiffness-injury pain due to awkward postures, continuous (isometric) or repetitive (isotonic) muscle contractions. Moreover, future studies should investigate different stretching protocols, types of stretching (static or PNF), frequency, intensity, duration, and time of stretch (before, after or during work)

so that more efficient protocols can be implemented. Finally, future studies should compare the effects of stretching across different occupational groups with distinct demands".[1] Maximum joint range of motion is an important parameter influencing functional performance and musculoskeletal injury risk.[2] It is well known that ample of information about stretching and stretching postures are available from the perspectives of neurology and biomechanics. However, the most fundamental biomechanical explanation, probably at an arthrokinematic level, of 'how stretch occurs' has been missing. "The scientific basis of the traditional rehabilitation technique of stretching with the goal of improving range of motion may actually be found in the cellular and molecular adaptive mechanisms of a muscle fiber. The increase in range of motion often reported after passive stretching may involve biomechanical, neurological, and molecular mechanisms".[3] "Contractures are a common complication of neurological and musculoskeletal conditions, and are characterised by a reduction in joint mobility. Stretch is widely used for the treatment and prevention of contractures. However, it is not clear whether stretch is effective. Stretch does not have clinically important effects on joint mobility in people with, or at risk of, contractures if performed for less than seven months. The effects of stretch performed for periods longer than seven months have not been investigated".[4] "Following spasticity, neural and mechanical changes of the paretic muscle often occur, which affect the muscle function. Functional stretching training into a rehabilitation program of subjects who had experienced a stroke was effective for decreasing spasticity in ankle joint".[5] Stretch of the muscles could be perceived as 'pleasant sensation' or 'unpleasant sensation', and the stretching ability (extensibility) of muscles can be measured as flexibility. Flexibility of the joints or the body are generally inhibited by 'unpleasant sensations' during stretch. Diminished flexibility or tightness of even one muscle is potent enough to engender irreparable detrimental effects on the whole body if it eludes judicious clinical interventions. This article will elucidate the neglected biomechanical fundamentals of stretch mechanism to refine the prophylactic and therapeutic prescriptions of stretching exercises.

Neglected Mechanical Basis of Skeletal Muscle Stretch

Though plenty of explanations and evidences exist to understand and apply stretch science, one important 'biomechanical fundamental' has been found missing (Figure 1 to 4). After analysing these schematic illustrations thoroughly, it would be possible to acquire dichotomous biomechanical insights, and curiosity to investigate and advance the stretch science using relevant technologies.

Figure 1: If the terminal points of an elastic structure (O and I) are held and pulled apart, the elastic will go undergo stretch. Skeletal muscles cannot be biomechanically stretched by such linear distraction because joints undergo angular motion.

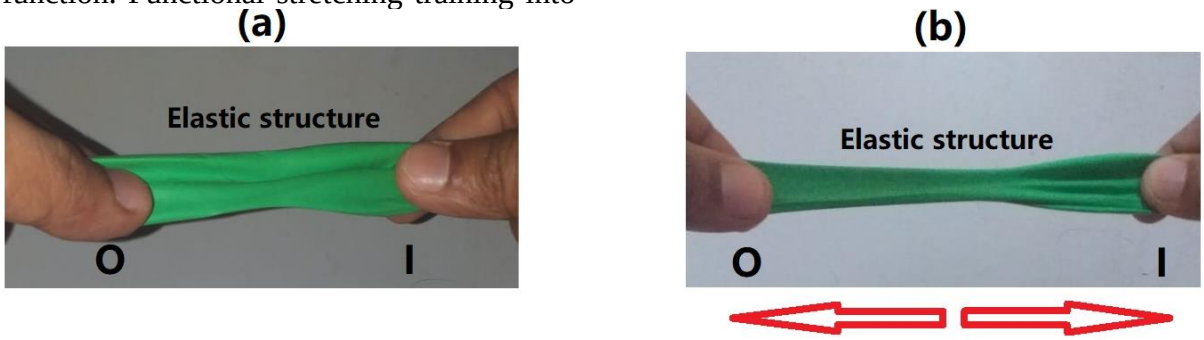


Figure 2: Skeletal joints cannot be pulled apart or distracted linearly in order to get a muscle stretch and stretch sensation. The question is how we are still able to get or sense 'stretch' by angular motion of the joints?

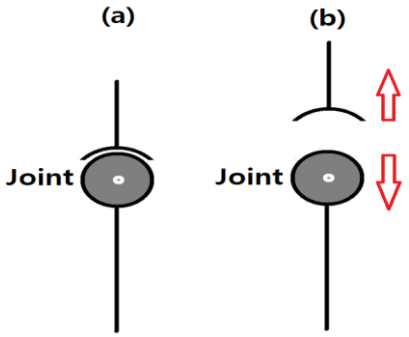


Figure 3: Because the points of origin (O) and Insertion (I) cannot be pulled linearly to get or sense 'stretch', Impingement Effect (IE) is the only way to stretch the skeletal muscle. IE could be as a result of a structure compressing the skeletal muscle near its origin or insertion or anywhere between origin and insertion. The structure that compresses the skeletal muscle could be any curved surface of the bone (spherical head, condyle, trochanter, tuberosity) or curved surface formed by multiple bones (ribs, vertebrae), in specific postures. Therefore, specific postures and curved surface are needed to get the IE to stretch a muscle or feel the stretch of a muscle

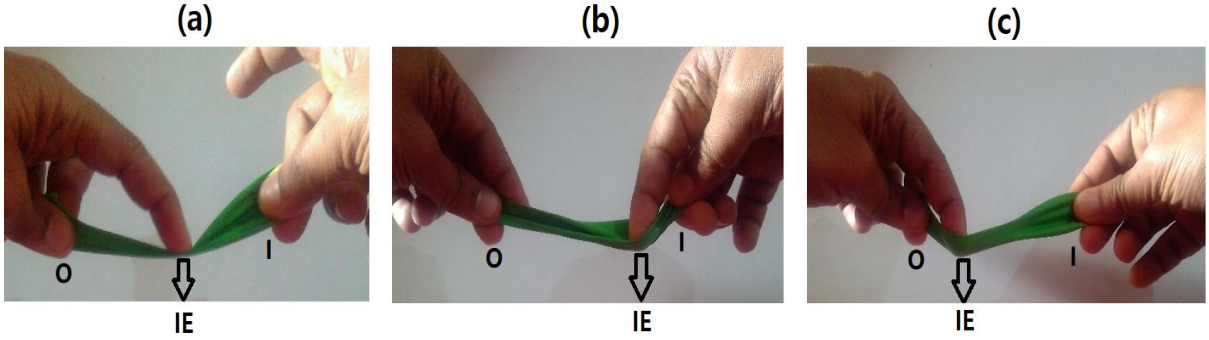
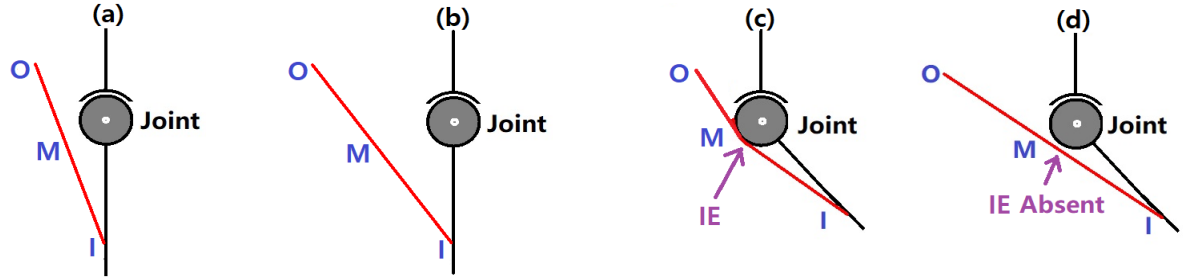


Figure 4: The range of motion (ROM) at which the IE occurs depends on the relationship between the muscles and the joint. In this figure, different points of origin (O) but similar point of insertion of two muscles have been shown as just one example (naturally quite a lot of variations in origin and insertion exists). As the angular motion of a joint continues, muscle (M) would meet a curved surface to experience an Impingement Effect (IE) that leads to 'Stretch' of a muscle and 'Stretch sensation' as well. The IE will not occur at the same angular displacement of the joint for these muscles. Muscles that traverse near the joint with a greater acute angle relationship (relate a and c) will experience IE earlier than the muscles with a lesser acute angle relationship (relate b and d). Therefore, in order for the arrangement 'b' to get the IE, the joint may have to move furthermore in degrees or may have to even reach the end range of angular motion. Keeping these analyses as basis, it is necessary to explore such interactions of different muscles and their respective joints in human body, essentially at arthrokinematic levels, using critical thinking.



Dichotomous Biomechanical Insights

Altered extensibility of muscles of dysfunctional joints and subsequent differences in stretch sensations (usually as compared to the same muscle on the unaffected limb) are known. But basically, many experimental studies may be needed to confirm the mechanics of IE in normal asymptomatic joints (Table 1) because stretch sensations are experienced at some angles of the apparently healthy joints also.

Table 1: Two views about IE of normal and asymptomatic joints.

Biomechanical Insight 1	Biomechanical Insight 2
Normal joints get displaced slightly out of their anatomical boundaries at certain angle(s) in the ROM due to stretch force or stretch posture and produce IE.	Only the slightly subluxated asymptomatic joints can cause IE at any angle in the ROM. It means, naturally at no point in ROM, the human muscles will be subjected to stretch and stretch sensations. Such subluxated joints may be stable (remain fixed at a location after having crossed the anatomical boundary with its axis deranged) or unstable (crosses the anatomical boundary with unstable axis and multidirectional instability), both cross the anatomical boundaries to cause IE.

Based on lifestyle, occupation and rate of ageing process, overuse/disuse of musculoskeletal system could lead to unnoticed or asymptomatic subluxation of joints also. IE should also be investigated on the joints of those with the history of complete dislocation of joint(s) and other musculoskeletal pathologies. Table 2 shows theoretical constructs based on the interpretations of neglected biomechanical fundamental of skeletal muscle stretch (Figure 1 to 4).

Table 2: Theoretical constructs based on Figure 1 to 4

1	IE could arrive early in the ROM of joints for the muscles that are traversing closer to the joint and are attached to the skeletons at very acute angles than the muscles of the same joint traversing at larger acute angles. Afferent neural signals arising during IE could be painful (bearable or unbearable). It must be verified with standard experiments if IE is (i) naturally absent but occurs only if the joints have unidirectional or multidirectional instability or subluxations (ii) naturally present but the neuromusculoskeletal system gets adapted through physical activity and good postural habits to increase the threshold of IE to produce stretch sensations, to develop/ensure painless and efficient ROM of joints. It should also be investigated if the full ROM of a healthy joint produce no 'stretch sensations' at all, and if this 'healthy joint' is enforced beyond their full ROM in order to 'feel the muscle stretch', will it pose risks to its stability?
2	It is possible that the IE may be occurring very early in the joint motion naturally but our neuromusculoskeletal adaptations to multiple postures and movements would have elevated the pain threshold, so we sense the stretch near or at the end of the ROM. Sometimes or in some individuals, same muscles of the right and left extremities may exhibit stretch sensitivity at different range of motion (asymmetrical flexibility of muscles). Stretch sensitivity that occurs before the joint reaches its end range of motion (ROM) could be a sign of an abnormality also (like joint subluxation, joint instability, neurological disturbance). Thus, neuromusculoskeletal adaptations to exercises could elevate the threshold for the IE to produce stretch sensations so as to ensure or facilitate effective full range of joint motion comfortably and contribute to enhancement of the exercise performance as well. Lowering of the pain threshold to IE should be regarded as abnormal and clinical examinations will help to identify the plausible cause.
3	Muscle damage and tightness caused by Sedentary life, Diseases & Delayed Onset Muscle Soreness could intensify the stretch sensations even earlier in the joint motion, and limit functional capabilities transiently or permanently.
4	IE sites on a muscle may be also multiple if it crosses more than one joint. For example, in the stretching postures for Biceps, humeral head and radial head could give IE proximally and distally, respectively. Detailed investigations are needed to confirm if these IE sites are (1) naturally present or absent (ii) only present after joints undergo derangement due to erroneous postures and movements, and injuries (iii) able to recede or disappear after practicing stretching exercises regularly and meticulously associated with restoration of normal axis. If IE sites are not naturally present, even few millimeters of displacement of joints from their anatomical and biomechanical boundaries (transient or permanent subluxation) could create IE site(s), and 'stretch sensations' produced by such IE site(s) should be both considered as abnormal and a favorable signal to be careful about the postures and movements.
5	If the joint motion is limited at any point in its ROM with intense stretch feeling, IE at that point could displace the articular ends out of the permitted anatomical boundaries causing sprain, strain or even subluxation/dislocation if the stretch force (either active or passive) is not carefully calibrated. It is also possible that if humans maintain full ROM of all the joints from very young age, the 'stretch sensations' may not be felt at all due to the absence of IE (joints remain within the anatomical boundaries throughout the range of motion) or 'elevated threshold' to get stretch sensations despite IE. We would have seen in clinical practice that some individuals not complaining of unpleasant stretch sensations throughout ROM, though they execute certain prescribed stretch postures perfectly. So, for such individuals, full ROM of active free exercises and strengthening exercises would suffice to maintain the biomechanics of the joints.
6	Stretching exercises could be the most indispensable to enhance/exhibit/retain versatile functional capabilities for healthy longevity and, at the same time it could be the riskiest exercise (causing disruption of axis and stability of the normal joint, exacerbating the symptoms of an already damaged joint, deteriorating various interconnected functions of the joint) if the selection/prescription of stretching exercises are not scientific (iatrogenic lesion) without profound knowledge in musculoskeletal anatomy, musculoskeletal examination and stretch science.

DISCUSSION

Flexibility of muscles is one of the crucial determinants of efficient body posture and movements. Efficient body postures and movements make the body 'metabolically efficient' which in turn will contribute to homeostasis. Inflexibility of muscles could adjoin with the factors leading to allostasis. Allostatic load is the long-term result of failed adaptation or allostasis, resulting in pathology and chronic illness, caused by failure of adaptation process of the complex physiological system to physical, psychosocial and environmental challenges or stress.[6] The tremendous prophylactic and therapeutic potential of stretching exercises are well-known. To have a long-term effect on musculoskeletal disorders (MSDs), physical therapists and occupational therapists should use stretching exercises in their treatment programs rather than solely rely on ergonomic modification.[7] Stretching and strengthening of cervical and thoracic spine muscles helps to alter the postural changes and maintain center of gravity.[8] "The acute effect of stretching appears to be a significant increase in range of motion mostly due to increased stretch tolerance and a significant reduction in most all forms of muscular performance. Stretching also results in significant acute stress-relaxation in the muscle, but does not appear to affect muscle stiffness/elasticity. Stretch training has a chronic effect of increasing range of motion, but also tends to increase the passive tension and stiffness of the musculature at the limits of motion".[9] Faulty postures and movements could lead to subluxation of joints, which might even remain asymptomatic or unnoticed for a long period of time (few typical examples of Simple Integrated Flexibility Tests (SIFT) are shown in Figure 5 and 6).

Figure 5: Normal shoulder joint enable formation of FAT triangle (Forearm, Arm and Trunk) in coronal plane as shown in 'a'. Usually, a lot of people have difficulty forming this FAT triangle on the dominant upper limb due to restriction in dominant shoulder (as shown in 'b'), and this problem also can be found as an asymptomatic dysfunction. Some individuals display trouble in forming FAT triangle on both the upper limbs. When the shoulder pathology worsens, the dysfunction becomes symptomatic associated with severe functional limitations, and the FAT triangle cannot be seen from coronal view but only from the sagittal view. Although the scientific rationale is yet to be established, some individuals respond satisfactorily to Biceps muscle stretch (in closed kinetic chain) to overcome such restrictions in shoulder joint.

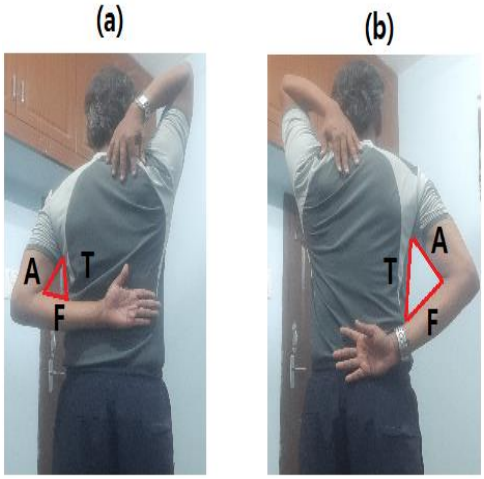
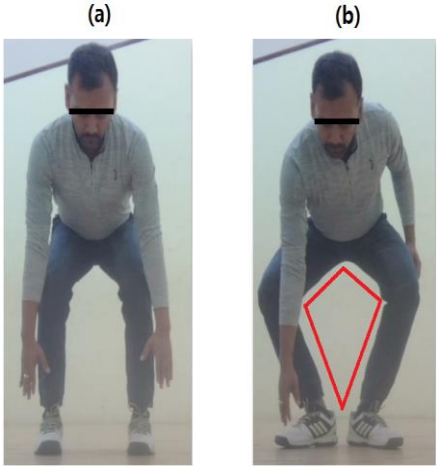


Figure 6: During forward bending, the lower limbs must be aligned parallel. But individuals with muscular tightness in lower limbs (regardless of the age) tend to apply an incorrect postural strategy by laterally deviating the thighs and feet to form a quadrilateral shape between the lower limbs.



Patients with shoulder pathology may not perform all the movements adequately to form FAT triangle in coronal plane.[10] In contrary, both incorrect and inadequate utilization of stretching exercises also could lead to joint dysfunctions, possibly, like subluxation of joints associated with misaligned joint axis, and aberrant postures and movements. Subluxation is usually defined as an incomplete dislocation of joint. From biomechanical view point, pathomechanical consequences of even few millimetres or degrees of displacement of the articular surfaces from the boundaries of articulation cannot be underestimated. A subluxated joint could unpredictably lead to enormous disturbances (especially if it eludes clinical interventions) like; unstable axis or misaligned axis, erroneous movements and postures, altered muscle recruitment, injury risks, asymptomatic postural and movement dysfunctions, increased joint friction, deformation and degeneration of the joints, joint stiffness, pain, crepitations, impingement on a nerve or muscle or blood vessel, restricted ROM, diminished muscular efficiency and functional capabilities, unpleasant stretch sensations, unhealthy ageing, contractures, deformities, proprioceptive dysfunction, balance impairment, detrimental effects on the affected joint(s) during sleep, dissemination of the dysfunction to other musculoskeletal units, etc., Dysfunction of even one joint complex could afflict other musculoskeletal complexes (example, unilateral plantar fasciitis). Impact of inflexible muscles on homeostasis and allostasis should not be overlooked because 'movement efficiency' and 'metabolic efficiency' are directly related. What would be the outcome of the morbidities (like Hemiplegia, Metabolic Syndrome) among the individuals, if these individuals already had sub-optimal flexibility of various muscle groups before acquiring such diseases? Multiple joint subluxations might be the consequence of multiple inflexible muscles accompanied by excruciating crippling effect on the body. Subluxations may not be directly measurable but the magnitude of their sabotaging influence on variables of health are measurable (example, flexibility tests like Sit and Reach). More advanced critical thinking and analyses are required to investigate the stretch mechanisms based on the dichotomous biomechanical insights and theoretical constructs discussed earlier. Anthropometry, Goniometry, Trigonometry, Inch tape measurements, visual diagnosis of normal and abnormal postures (static and dynamic), and the ability to rectify static and dynamic postural dysfunctions are all the essentials of applied stretch science. Thus, objective assessments of flexibility of muscles should be prioritized wherever relevant with the help of suitable instrument/technology, to generate reproducible facts about the precision of diagnosis and interventions. Facilitating Accountable Critical Thinking (FACT) should be given prime importance in medical education and health care system, so that every knowledge is allowed to be disseminated and practiced only if sufficient facts are available.[11] Maintaining the natural congruence of all the joints and 'joint-specific arthrokinematics' through preservation of their 'axis' is one of the integral parts of health and healthy ageing. "In the medical world, the term "congruence" is used to describe by visual inspection how the articular surfaces mate each other, evaluating the joint capability to distribute an applied load from a purely geometrical perspective. Congruence is commonly employed for assessing articular physiology and for the comparison between normal and pathological states".[12] "The convex-concave patterns if interpreted correctly, serve as a cornerstone to understanding the essential mechanism of arthrokinematics. Let us appreciate the natural patterns of arthrokinematics for what they were intended to do, while respecting their possible limitations in directing treatment approaches".[13] Stretching exercises, if meticulously performed, could contribute to improved exercise performance, thereby they also support

'Accurate Interpretation of Stability of Human Health and Ageing Trajectory through a Single Objective Measure of Homeostasis'.

CONCLUSION

Stretching exercises are incorporated in exercise and rehabilitation programs to derive joint-specific improvements and overall functional abilities. Stretch postures can be used in clinical diagnosis, prophylactic regimens and therapeutics. Many static and dynamic postural dysfunctions caused by inflexible skeletal muscles could represent the earliest asymptomatic dysfunctions of unhealthy ageing even among the young persons and children, that can be only understood with profound clinical experience. Health and healthy ageing need preservation of axis of all the moveable axial and appendicular joints which would not be possible in the presence of highly interconnected inflexible muscles and joint instability. From the perspective of theoretical constructs derived from dichotomous biomechanical insights, stretching exercise is the most indispensable efficacious exercises to preserve perfect joint axis, and the riskiest of all exercises if the minute details like IE and arthrokinematics of the joints are ignored.

Acknowledgement: None

Conflict of Interest: None

Source of Funding: None

Ethical Approval: Not Applicable

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How to cite this article: R. Vinodh Rajkumar. Neglected mechanical basis of skeletal muscle stretch: dichotomous biomechanical insights. *International Journal of Science & Healthcare Research.* 2022; 7(3): 149-156. DOI: *https://doi.org/10.52403/ ijshr.20220722*

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