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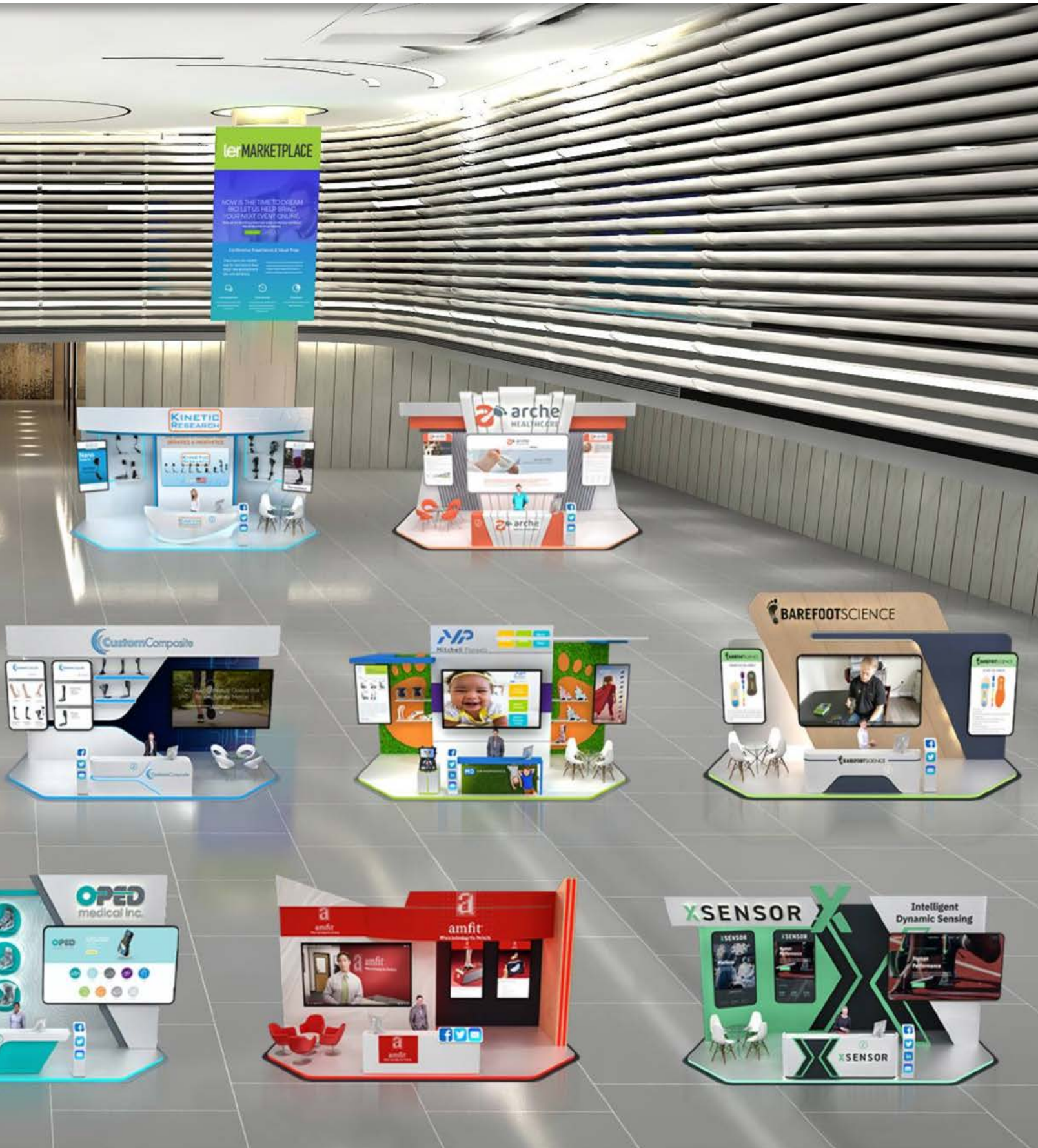

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April 2022 contents

LETTER TO EDITOR

AD INDEX

NEW & NOTEWORTHY

THE LAST WORD

COVER STORY

CLINICAL PERSPECTIVE: ON SITTING

SHORTTAKES FROM THE LITERATURE

FEATURES

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Lower Extremity Review informs healthcare practitioners on current developments in the diagnosis, treatment, and prevention of lower extremity injuries. LER encourages a collaborative multidisciplinary clinical approach with an emphasis on functional outcomes and evidence-based medicine. LER is published monthly, except for a combined November/December issue and an additional special issue in December, by Lower Extremity Review, LLC.

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Lower Extremity Review Mission

Showcasing evidence and expertise across multiple medical disciplines to build, preserve, and restore function of the lower extremity from pediatrics to geriatrics.

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- Biomechanics matter
- Diabetic foot ulcers can be prevented
- Injury prevention is possible
- Collaborative care leads to better outcomes

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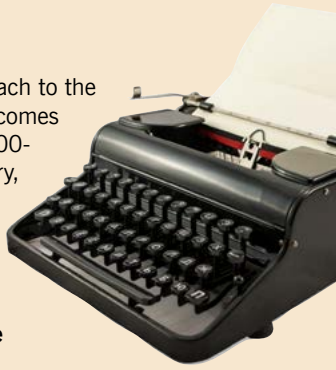
LER encourages a collaborative multidisciplinary clinical approach to the care of the lower extremity with an emphasis on functional outcomes using evidence-based medicine. We welcome manuscripts (1000-2000 words) that cross the clinical spectrum, including podiatry, orthopedics and sports medicine, physical medicine and rehabilitation, biomechanics, obesity, wound management, physical and occupational therapy, athletic training, orthotics and prosthetics, and pedorthics.



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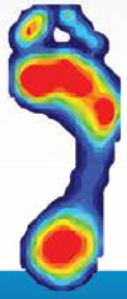

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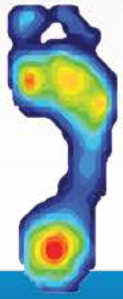

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Letter to the **Editor**

What Are You Looking For?

In response to "The Future of Orthotics Manufacturing," by ***Cary Groner; July 2021****.*

A large part of 3D printing orthotics is to leverage different aspects of the additive process, without necessarily altering the type and style of orthotics practitioners are looking for. Perhaps another reason why 3D printing remains on the "ever-receding horizon" is because of the way segmental stiffness, for one example, has been applied. To design an orthotic with increased (or decreased) density and intricate geometries of various lattice structures in areas of increased (or decreased) 'segmental values' becomes more of an algorithm-based approach rather than a step-up design approach. Our experience is that practitioners still want to see an extrinsic post or a fascial groove or a Kirby skive, for example. This is how they have been taught and what they recognize and know. They know how to prescribe them, how to order them, and what to expect from them.

Further, many practitioners are also not exposed to the design softwares capable of 3D print-ready orthotics, or for that matter, the various types of 3D printing technologies, which is perhaps another reason for the slow acceptance of this technology, since 3D printing is not fully taught within the curricula of most podiatry schools worldwide.

Of the most common 3D printing technologies mentioned, the one left out—MJF (multi-jet fusion)—is likely the best positioned to accelerate this change (albeit with an extremely hefty pricetag) due primarily to the speed and volume at which it can produce orthotics. This technology will generally not have lattice structures, but rather various other additive advantages that practitioners will far easier accept and clinically recognize. In fact, there are a number of labs around the world that are already producing thousands of 3D printed orthotics and for some years already. We were at the forefront of this adoption in North America and have seen the remarkable growth and adoption of 3D printing both with clinicians and patients alike.

Brandon Maggen*, NHD, HRD, MSc ,PhD, FFPM RCPS (Glasg)*

Vice President, Technical and Business Development/3D Orthotics

Leo Lab (Leading Edge Orthotics Laboratories)

Vaughan, Ontario, Canada

LONGER FASCICLE LENGTH MAY CAUSE DEFICIT IN NON-SURGICAL HEALING OF ACHILLES

Achilles tendon rupture appears to alter stiffness and length of the tendon. These alterations may affect the function of tendon in force transmission and in energy storage and recovery. We studied the mechanical properties of the Achilles' tendon post-rupture and their association with function.

Methods Twenty-four (20 males, 4 females) participants (mean age: 43 y, 176 cm, 81 kg) were recruited. Ultrasonography and dynamometry were used to assess the muscle-tendon unit morphological and mechanical properties of non-surgically treated patients 1-year post rupture.

Findings Injured tendons were longer with difference of 1.8 cm (95%CI: 0.5-1.9 cm; $P<0.001$), and thicker by 0.2 mm (0.2-0.3 mm; $P<0.01$). Medial gastrocnemius cross-sectional area was 1.0 cm^2 smaller (0.8-1.1 cm^2; $P<0.001$), fascicles were 0.6 cm shorter (0.5-0.7 cm; $P<0.001$) and pennation angle was 2.5-degree higher (1.3-3.6 degrees; $P<0.001$) when compared to the uninjured limb. We found no differences between injured and uninjured tendon stiffness 1-year post-rupture (mean difference: 29.8 N/mm, -7.7–67.3 N/mm; $P=0.170$). The injured tendon showed 1.8 mm (1.2–2.4 mm; $P<0.01$) lower elongation during maximal voluntary isometric contractions. Patient reported functional outcome was related to the tendon resting length ($\beta=0.68$, $r(10)=4.079$, $P=0.002$). Inter-limb differences in the medial gastrocnemius fascicle length were related to inter-limb differences in maximum contractions ($\beta=1.17$, $r(14)=2.808$, $P=0.014$).

Interpretation Longer Achilles tendon resting length was associated with poorer self-evaluated functional outcome. Although the stiffness of non-surgically treated and uninjured tendons was similar 1-year post rupture, plantar flexion strength deficit was still present, possibly due to shorter medial gastrocnemius fascicle length. ler

Source: *Khair RM, Stenroth L, Cronin NJ, Reito A, Paloneva J, Finni T. Muscle-tendon morphomechanical properties of non-surgically treated Achilles tendon 1-year post-rupture. Clin Biomech (Bristol, Avon). 2022;92:105568. Use per Creative Commons CC BY.*

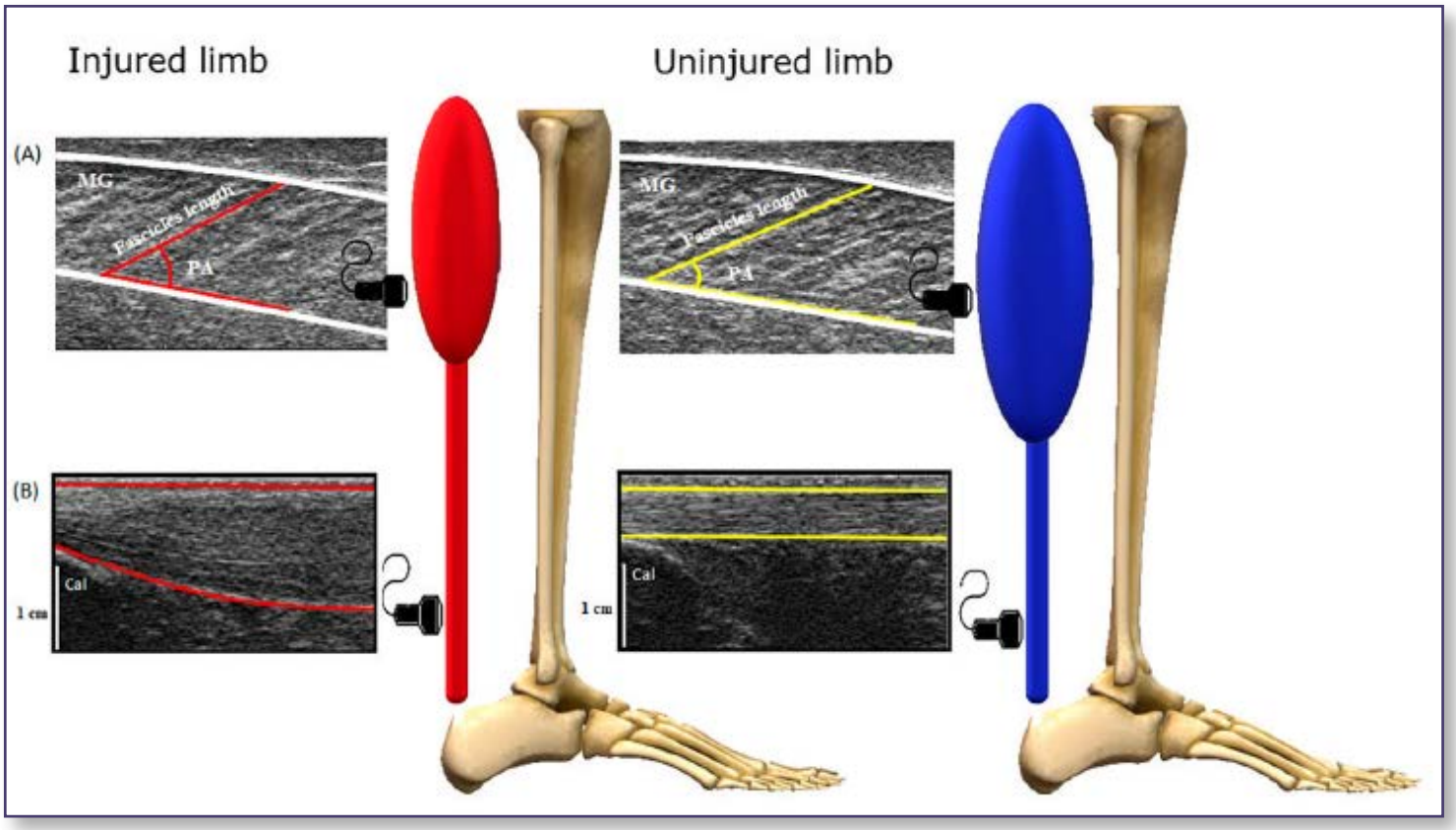
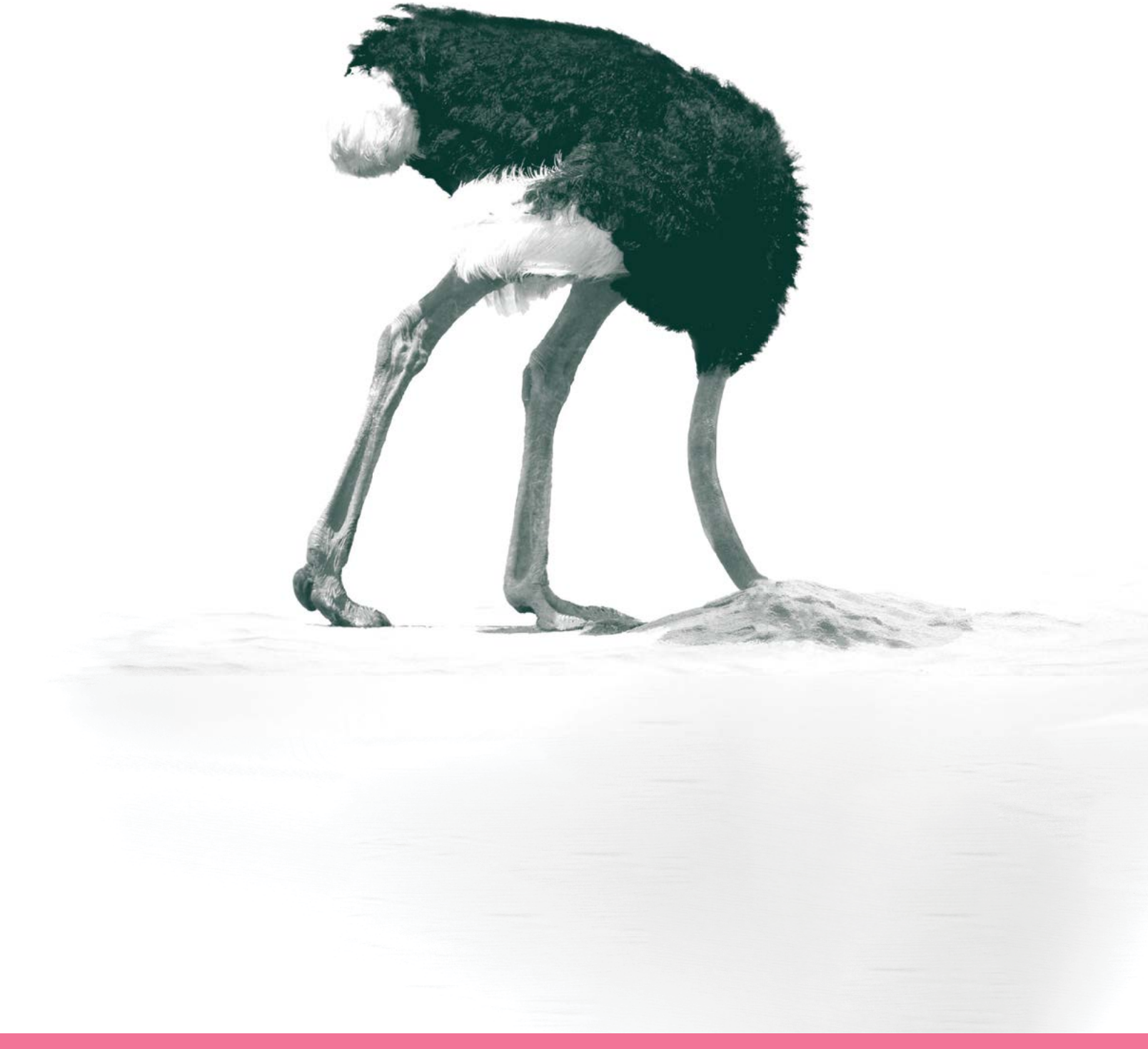


Figure. Ultrasonographic images of muscle-tendon unit structural properties 1-year post-rupture in both limbs. A) images of MG muscle where pennation angle and fascicle length were analyzed. B) Images where AT thickness was measured 1 cm away from the calcaneal insertion. Injured limb AT was longer and thicker than the uninjured AT. At rest, MG had a smaller CSA with longer and more pennate fascicles.

Continued on page 12



Continued from page 10

MORE SLEEP = LESS CALORIC INTAKE

In a randomized clinical trial of 80 adults (51.3% male; mean age 29.8 yrs; mean BMI, 28.1) with habitual sleep less than 6.5 hours per night, those randomized to a 2-week sleep extension intervention significantly reduced their daily energy intake by approximately 270 kcal compared with the control group. Total energy expenditure did not significantly differ between the sleep extension and control groups, resulting in a negative energy balance with sleep extension. While the intervention group had been counseled to increase sleep to 8.5 hours per night, actual sleep duration increased 1.2 hours per night for a total of 7.7 hours.

In their conclusion, the authors highlighted the importance of improving and maintaining adequate sleep duration as a public health target for obesity prevention and increasing awareness about the benefits of adequate sleep duration for healthy weight maintenance.

Source: *Tasali E, Wroblewski K, Kahn E, Kilkus J, Schoeller DA. Effect of sleep extension on objectively assessed energy intake among adults with overweight in real-life settings: a randomized clinical trial. JAMA Intern Med. 2022;182(4):365–374.*

NEW PREVENTION OF VTE CONSENSUS STATEMENT RELEASED

The first ever international consensus statement with recommendations for the prevention of venous thromboembolism (VTE) after orthopedic surgeries has been published in the *Journal of Bone and Joint Surgery*. Developed by 600 experts from around the globe, the statement seeks to standardize treatment guidelines and decrease the occurrence of this common post-surgical complication. Key highlights among the recommendations include:

- Mechanical compressive devices can be used routinely in patients undergoing total hip arthroplasty or total knee arthroplasty as VTE prophylaxis.
- For the majority of surgical procedures, it appears that aspirin and intermittent pneumatic compression devices may be adequate.
- Development of VTE is influenced by genetic and other patient-specific predispositions.
- Recognizing these factors may help tailor the VTE prophylaxis accordingly.
- Currently, the industry lacks a validated and appropriate risk stratification system for VTE or bleeding; the medical community desperately needs those measures and stratification systems.

Source: *Swiontkowski M, Parvizi J. International Consensus Meeting on Venous Thromboembolism. J Bone Joint Surg Am. 2022 Mar 16;104(Suppl 1):1-3.Intern Med. 2022;182(4):365–374.*

1ST COVID-19 BREATHALYZER TEST GETS FDA OK

The US Food and Drug Administration issued an emergency use authorization (EUA) for the first COVID-19 diagnostic test that detects chemical compounds in breath samples associated with a SARS-CoV-2 infection. The test can be performed in environments where the patient specimen is both collected and analyzed, such as doctor's offices, hospitals, and mobile testing sites, using an instrument about the size of a piece of carry-on luggage. The test is performed by a qualified, trained operator under the supervision of a health care provider licensed or authorized by state law to prescribe tests and can provide results in less than 3 minutes.

"Today's authorization is yet another example of the rapid innovation occurring with diagnostic tests for COVID-19," said Jeff Shuren, MD, JD, director of the FDA's Center for Devices and Radiological Health. "The FDA continues to support the development of novel COVID-19 tests with the goal of advancing technologies that can help address the current pandemic and better position the U.S. for the next public health emergency."

Continued on page 14

Don’t bury your head in the past

The future is far too bright

Continued from page 12

The performance of the InspectIR COVID-19 Breathalyzer was validated in a large study of 2,409 individuals, including those with and without symptoms. In the study, the test was shown to have 91.2% sensitivity (the percent of positive samples the test correctly identified) and 99.3% specificity (the percent of negative samples the test correctly identified). The study also showed that, in a population with only 4.2% of individuals who are positive for the virus, the test had a negative predictive value of 99.6%, meaning that people who receive a negative test result are likely truly negative in areas of low disease prevalence. The test performed with similar sensitivity in a follow-up clinical study focused on the omicron variant.

The InspectIR COVID-19 Breathalyzer uses a technique called gas chromatography gas mass-spectrometry (GC-MS) to separate and identify chemical mixtures and rapidly detect 5 Volatile Organic Compounds (VOCs) associated with SARS-CoV-2 infection in exhaled breath. When the InspectIR COVID-19 Breathalyzer detects the presence of VOC markers of SARS-CoV-2, a presumptive (unconfirmed) positive test result is returned and should be confirmed with a molecular test. Negative results should be considered in the context of a patient's recent exposures, history, and the presence of clinical signs and symptoms consistent with COVID-19, as they do not rule out SARS-CoV-2 infection and should not be used as the sole basis for treatment or patient management decisions, including infection control decisions.

InspectIR expects to be able to produce approximately 100 instruments per week, which can each be used to evaluate approximately 160 samples per day. At this level of production, testing capacity using the InspectIR COVID-19 Breathalyzer is expected to increase by approximately 64,000 samples per month. ler

Source: *US Food and Drug Administration. Coronavirus (COVID-19) update: FDA authorizes first COVID-19 diagnostic test using breath samples. Published April 14, 2022. Available at https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-fda-authorizes-first-covid-19-diagnostic-test-using-breath-samples. Accessed April 15, 2022.*

PLANTAR PRESSURES IN HIKING BOOTS

The purpose of this study was to investigate the influence of heel-to-toe drop (heel drop) modifications of a hiking shoe on plantar pressure distribution and perceived comfort before and after walking. Data of 3 shoe conditions with a low (11 mm), medium (16 mm), and high (21 mm) heel drop were obtained of 12 healthy male participants (mean age: 23.8 ± 2.8 yrs.) before (pre-test) and after a 45-minute walk in a park (post-test). Two-way repeated-measures analysis of variance (ANOVA) was applied to investigate differences between the 3 shoe types at the 2 time points and over time. Post-hoc analyses showed few significant differences in pressure and comfort parameters between shoe conditions at the 2 time points.

Over time, however, several significant changes in comfort measures and pressure distribution were observed depending on the shoe condition. Most of the plantar pressure changes were seen in the hiking shoe with the medium heel drop showing significantly increased pressures values in the toe and forefoot area after the walk. Comfort measures deteriorated from the pre- to the post-test, in particular for the hiking shoe with the high heel drop. The results of the study showed that comfort and pressure parameters altered from walking for 45 minutes depending on the shoe condition and that the modification of the heel drop affected pressure parameters and comfort parameters in different ways. These findings may have implications for future considerations of values for the heel drop in hiking shoes. ler

Source: *John S, Eisenmann M, Witte K. Plantar pressure distribution and perceived comfort in hiking boots with different heel-to-toe drops before and after 45 minutes of walking. Footwear Sci. 2021. DOI: 10.1080/19424280.2021.1991007.*

SHOCK-ABSORBING FLOORING GETS MIXED REVIEWS

Falls and fall-related injuries are a major problem for older adults in both hospitals and care homes. Shock-absorbing flooring (such as carpet, sports floors, or specially designed floors) provides a more cushioned surface and is one potential solution to help reduce the impact forces from a fall. The aim of this study was to summarize what is known about shock-absorbing flooring for reducing injurious falls in hospitals and care homes.

From literature searches, we identified relevant studies on shock-absorbing flooring use in hospitals and care homes. We gathered data on the quality of the studies' methods, what and who the studies involved, and the study findings. Members of the public were involved throughout the project. They helped improve the clarity of the reporting and collabo-

Continued on page 17

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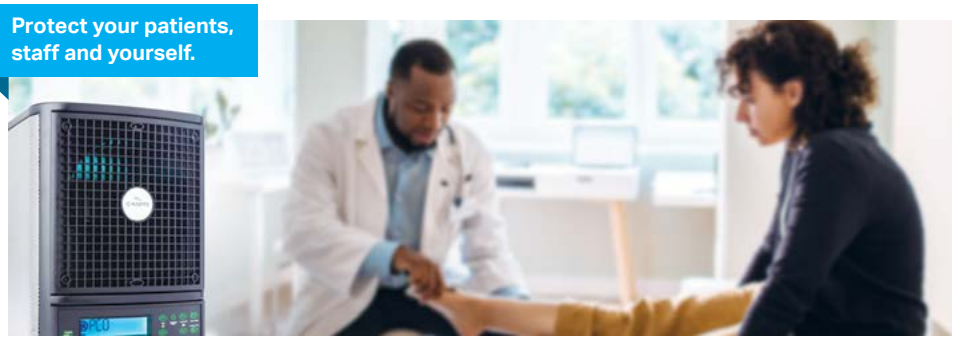

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Continued from page 14

rated in meetings to help guide the study team.

Findings: One high-quality study in a care home found that vinyl overlay with novel shock-absorbing underlay was no better at reducing injuries than vinyl overlay with plywood underlay on concrete subfloors. We found very low-quality evidence that shock-absorbing flooring may reduce injuries in hospitals and care homes, without increasing falls; if this were true, then economic evidence suggested that shock-absorbing flooring would be the best-value option for patients (lower cost and improved outcomes). There was insufficient evidence to determine the effects of shock-absorbing flooring on fractures or head injuries, although wooden subfloors resulted in fewer hip fractures than concrete subfloors. Shock-absorbing flooring made it harder for staff to move equipment such as beds and trolleys and led to staff changing how they work.

Implications: The evidence suggests that one type of shock-absorbing floor may not work in care homes, compared with rigid flooring; however, gaps still exist in the knowledge. The evidence in favor of shock-absorbing flooring was of very low quality, meaning it is uncertain. There is a lack of robust evidence in hospitals, which often have concrete subfloors and different population characteristics. If planning to install shock-absorbing flooring, it is important to consider the wider impacts on the workplace and how best to manage these.

Source: *Drahota A, Felix LM, Raftery J, et al. Shock-absorbing flooring for fall-related injury prevention in older adults and staff in hospitals and care homes: the SAFEST systematic review. Health Technol Assess. 2022;26(5):1-196.*

PRE-CLINICAL DRUG STUDY SHOWS PROMISE IN PARKINSONIAN DISORDER

A new study in the *Journal of Parkinson's Disease* describes a study evaluating the efficacy of ATH434 in genetically altered mice that develop manifestations of Multiple System Atrophy (MSA). The study was led by David I. Finkelstein, PhD, Head of Parkinson's Disease Laboratory at the Florey Institute of Neuroscience and Mental Health and the University of Melbourne.

Multiple System Atrophy is a rare, neurodegenerative disease characterized by failure of the autonomic nervous system and impaired movement. The symptoms reflect the progressive loss of function and death of different types of nerve cells in the brain and spinal cord. It is a rapidly progressive disease and causes profound disability. MSA is a Parkinsonian disorder characterized by a variable combination of slowed movement and/or rigidity, autonomic instability that affects involuntary functions such as blood pressure maintenance and bladder control, and impaired balance and/or coordination that predisposes to falls. A pathological hallmark of MSA is the accumulation of the protein α-synuclein within glia, the support cells of the central nervous system, and neuron loss in multiple brain regions. MSA affects approximately15,000 individuals in the United States, and while some of the symptoms of MSA can be treated with medications, currently there are no drugs that are able to slow disease progression and there is no cure.

In this study, genetically altered, or transgenic, mice overexpress α–synuclein, develop glial cell inclusions, and manifest motor and non-motor aspects of MSA. Animals received ATH434 in food or a control diet for 4 months starting at 12 months of age. Western blot analysis was used to assess oligomeric and aggregated forms of α-synuclein levels in brain and stereology was used to quantitate the number of neurons and glial cell inclusions in the substantia nigra pars compacta.

The study demonstrated that in the studied brain region, ATH434 treatment reduced both the toxic oligomeric and aggregated forms of α–synuclein, a central nervous system protein important for normal function of nerve cells. At the same time, ATH434 treatment reduced the cardinal pathology of MSA (glial cell inclusions), reduced brain iron, preserved neurons, and improved motor performance. The publication concluded that ATH434 is a promising small molecule drug candidate that has potential for treating MSA. ATH434 has been granted Orphan designation for the treatment of MSA by the U.S. FDA and the European Commission.

Source: *Finkelstein DI, Shukla JJ, Cherny, RA, et al. The compound ATH434 prevents alpha-synuclein toxicity in a murine model of Multiple System Atrophy. J Parkinson's Dis. 2022;12(1):105-115.*

PILATES EFFECTIVE AT IMPROVING POSTURE IN YOUNG CHILDREN

In a recently released study from Turkey, the authors sought to investigate the effects of Pilates exercises on posture and physical fitness parameters. They assigned 66 school children (5-6 years) to Pilates or control groups. The Pilates intervention consisted of twice-a-week sessions for 10 weeks, while the control group followed established daily routines. Posture was assessed using the New York Posture Rating Chart; the Eurofit test

Continued on page 19

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Continued from page 17

battery was used to evaluate physical activity.

Their findings showed statistically significant improvements in the New York Posture Rating chart test, Flamingo Balance, Sit and Reach, Standing Broad Jump, 30-second Sit-Up, Bent Arm Hang, and 20-Meter Shuttle Run test scores.

The authors concluded that Pilates has positive effects on physical fitness parameters and postural evaluation in this age group, and they suggest it can be considered as an engaging alternative for physical activity. ler

Source: *Ozturk N, Unver F. The effects of Pilates on posture and physical fitness parameters in 5–6 years old children: A non-randomized controlled study. J Bodywork Move Ther. Epub Ahead of Print. March 20, 2022. Available at https://www.sciencedirect.com/science/article/abs/pii/S1360859222000511. Accessed April 15, 2022.*

FIBER NOT THE SOURCE OF BLISTERS IN WET SOCKS

Socks are of fundamental importance in reducing friction and in controlling the temperature and humidity of the foot, thus preventing the appearance of blisters. However, the influence of sock fibers (synthetic vs. natural) on blistering during long-distance hiking has received little research attention. This study evaluates the influence of sock fibers on the appearance of foot blisters in hikers.

Method: The sample consisted of 203 male and female hikers, mean age 35.8 ± 14.5 years, from 22 countries. All were interviewed and assessed at shelters on the French route of the Camino de Santiago (Spain). Sociodemographic and clinical data were obtained for each hiker; other study data included the number of blisters on the foot, whether the socks were wet at the end of the day, the model of sock used and the nature of its constituent fibers.

Results: Among the hikers interviewed, 68.5% presented foot blisters. 74.2% used socks with predominantly synthetic fibers, compared to 25.9% whose socks were mainly composed of natural fibers. On average, they had walked 253.7 km (157.6 miles). Hiking in wet socks was associated with a 1.94 times greater risk of experiencing foot blisters (95% CI 1.04–3.61) (P=0.035). Multivariate analysis showed that the proportion of natural/synthetic fibers in the composition of the sock was not related to the presence of blisters.

Conclusions: The use of wet socks heightens the risk of foot blisters in hikers, but the composition of the sock is not associated with blistering. We recommend hikers change their socks in long stages to maintain feet dry and so avoiding the development of blisters. ler

Source: *Esther CL, Gabriel GN, Raquel SR, Alfonso MN. The influence of sock composition on the appearance of foot blisters in hikers. J Tissue Viability. 2022:S0965-206X(22)00021-3. Available at https://www.sciencedirect.com/science/article/pii/S0965206X22000213?via%3Dihub. Accessed April 15, 2022.*

ORTHOTICS AND PROSTHETICS OUTCOMES RESEARCH PROGRAM (OPORP)

SELF-MYOFASCIAL RELEASE, REMOTE HAMSTRING STRETCHING EFFECTS, AND MYOFASCIAL CHAINS

Classic anatomy textbooks describe the hamstring muscles from a traditional mechanistic view as being isolated from the adjacent structures. However, recent research has changed this perspective, proposing a connective tissue link between the active components of the movement system to form an extensive network of myofascial chains, or meridians. Of these meridians, there is most anatomical evidence for the superficial back line (SBL). This myofascial chain connects the hamstring muscles with the gastrocnemius muscles and the plantar fascia caudally, and with the thoracolumbar fasciae, the erector spinae muscle, and the epicranial aponeurosis cranially.

Functionally, anatomical studies have demonstrated the role of these fascia in the transmission of biomechanical force between the different regions of the body connected by the chains. The hamstring muscles are described as forming part of myofascial chains or meridians, and the

Continued on page 20

Continued from page 19

superficial back line (SBL) is one such chain. Good hamstring flexibility is fundamental to sporting performance and is associated with prevention of injuries of these muscles.

The aim of this study was to measure the effect of self-myofascial release (SMR) on hamstring flexibility and determine which segment of the SBL resulted in the greatest increase in flexibility.

Methods: 94 volunteers were randomly assigned to a control group or to 1 of the 5 intervention groups. In the intervention groups, SMR was applied to 1 of the 5 segments of the SBL (plantar fascia, posterior part of the sural fascia, posterior part of the crural fascia, lumbar fascia, or epicranial aponeurosis) for 10 min. The analyzed variables were hamstring flexibility at 30 s, 2, 5, and 10 min, and dorsiflexion range of motion before and after the intervention.

Results: Hamstring flexibility and ankle dorsiflexion improved when SMR was performed on any of the SBL segments. The segments with the greatest effect were the posterior part of the sural fascia when the intervention was brief (30 s to 2 min) or the posterior part of the crural fascia when the intervention was longer (5 or 10 min). In general, 50% of the flexibility gain was obtained during the first 2 min of SMR.

Discussion: This study found that performing SMR on any segment of the SBL resulted in a statistically significant increase in hamstring flexibility and ankle dorsiflexion. These results reinforce the concept of the chain as an entity, not just from an anatomic perspective, as has been described previously, but also as a functional structure as reported in recent studies. The segment found to affect hamstring flexibility most was the plantar fascia. The effects were greater especially when the foam roller was applied for relatively short times.

This implication is not new, and the results are similar to those observed when self-massage of the plantar fascia with a ball was performed for 5 min, or to the results with self-massage for 5 min. Comparable results to ours were obtained when treatment was applied by a therapist over various sessions; they also found better results when the SMR was self-applied. Our results show that when the foam roller was applied for longer periods of time (from 5 to 10 min), the segments of the thoracolumbar fasciae and erector muscles, and the posterior part of the sural fascia had more impact on hamstring flexibility. Previous studies observed an improvement in dorsiflexion but did not assess hamstring flexibility. Other investigations also found increased ankle dorsiflexion following self-massage of the posterior part of the lower limb, but did not establish which fascial segment had the greatest effect.

The effects of SMR to each of these segments on hamstring flexibility may be due to the continuity, overlapping and compartmentalization of the muscular tissue by the fascia. A possible explanation for the better results when SMR was performed on the plantar fascia is the significant fascial continuity, via the Achilles tendon, between the plantar fascia and the posterior part of the sural fascia. In the same way, SMR application to the thoracolumbar fascia and erector muscles can be explained by the anatomical connection between the thoracolumbar fascia and the ham-

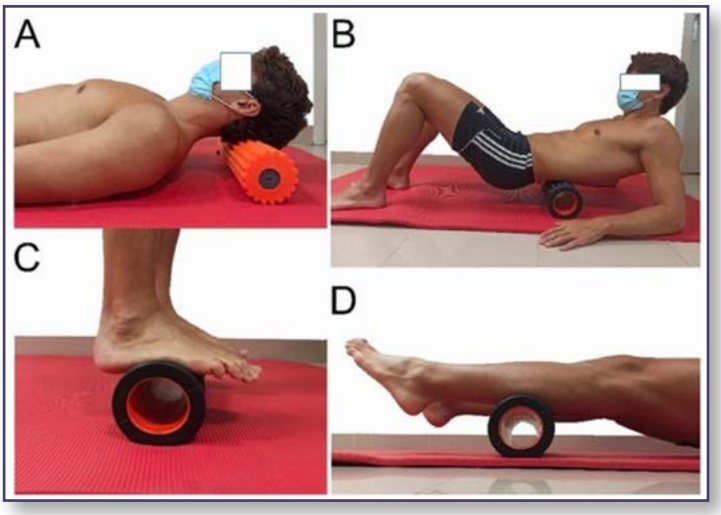


Figure. Interventions. (A) intervention to the epicranial aponeurosis, (B) thoracolumbar facia and erector muscles intervention, (C) plantar fascia and (D) posterior part of the sural fascia.

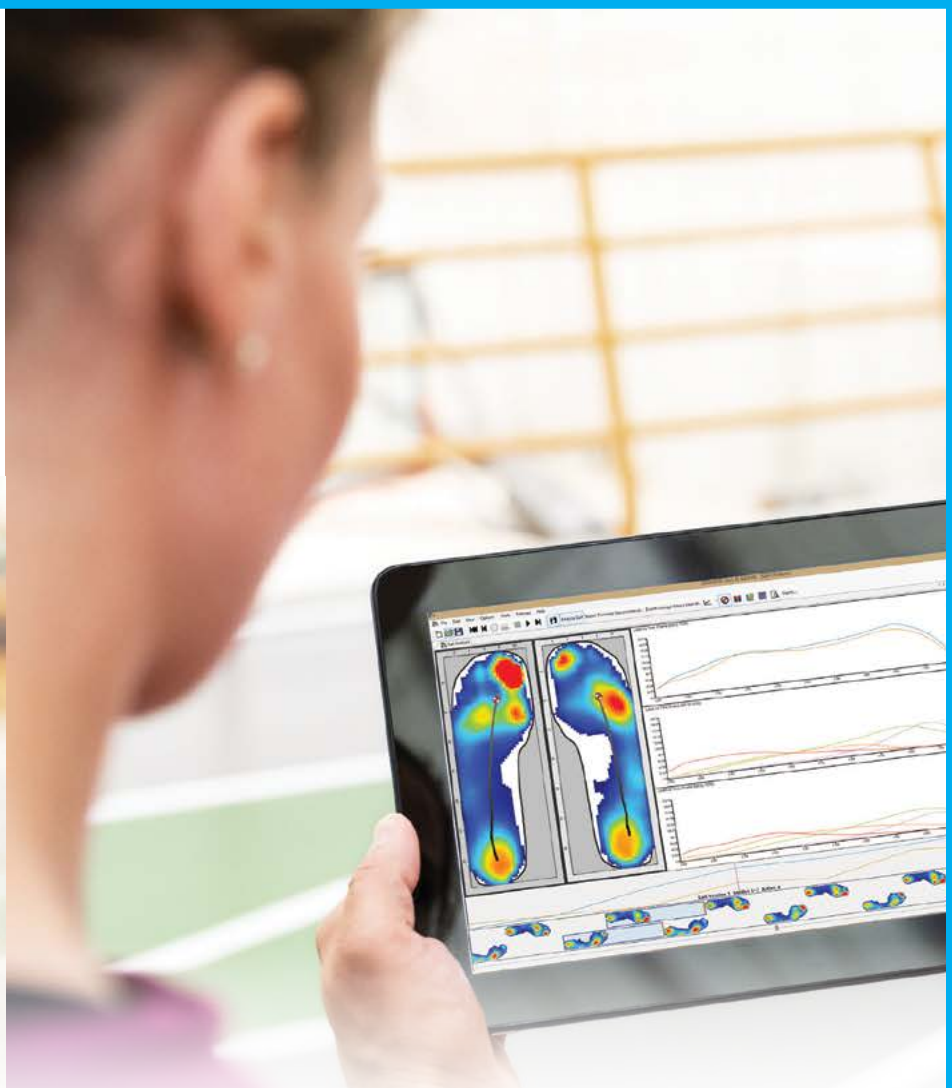
string muscles via the sacrotuberous ligament. Other studies have found significant improvements by combining the foam roll with passive movements. However, it appears that the use of other therapies such as focal vibration may generate superior improvements. Despite these results, the selling price of focal vibration is much higher than that of foam roll. For this reason, it could be interesting to use therapies such as focal vibration within a therapeutic treatment with the physical therapist and the use of the foam roll as a self-treatment for the patient.

Regarding the results obtained, there is a fascial structural relationship in the entire posterior chain. However, there is also a neurophysiological explanation: different manual techniques can generate viscoelastic and hypoalgesic effects through a model based on the fact that a mechanical stimulus initiates a chain of spinal, peripheral, and/or supraspinal neurophysiological events that would produce these changes at a distance even in distant areas such as the suboccipital region.

In summary, the present study demonstrates that the SBL can be considered a functional structure, since SMR application to any of its component segments improved hamstring flexibility and ankle dorsiflexion, the segments with the greatest effects being the plantar fascia (for short treatment duration) and the thoracolumbar fascia and erector muscles (for longer treatment duration). The results suggest that this technique could be effective both in rehabilitation and sports to enhance hamstring flexibility remotely.

In conclusion, the present study demonstrates that the SBL can be considered a functional structure, as the application of SMR on any of its component segments improved hamstring flexibility and ankle dorsiflexion. The use of this treatment could be effective in both rehabilitation and sport to improve hamstring flexibility at a distance. ler

Source: *Fauris P, López-de-Celis C, Canet-Vintró M, et al. Does self-myofascial release cause a remote hamstring stretching effect based on myofascial chains? A randomized controlled trial. Int J Environ Res Public Health. 2021 Nov 24;18(23):12356. Use is per Creative Commons CC BY.*



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Hamstring Strain Injury Rehabilitation—Part II*

By Jack T. Hickey, PhD, AEP; David A. Opar, PhD; Leigh J. Weiss, DPT, PT, ATC; and Bryan C. Heiderscheit, PhD, PT

Impaired performance and reinjury rates are high for this common injury. This narrative review discusses the causes and mechanisms of hamstring strain injury and current clinical concepts related to the rehabilitation process, with the aim of helping practitioners improve athletes' outcomes.

Hamstring strain injuries are common among athletes and often require rehabilitation to prepare players for a timely return to sport performance while also minimizing reinjury risk. Return to sport is typically achieved within weeks of the injury; however, subsequent athlete performance may be impaired, and reinjury rates are high. Improving these outcomes requires rehabilitation practitioners (eg, athletic trainers and physical therapists) to understand the causes and mechanisms of hamstring strain injury, know how to perform a thorough clinical examination (both covered in Part I in the March issue), and progress loading to the site of injury safely and effectively. This narrative review discusses current clinical concepts related to these aspects of rehabilitation for hamstring strain injury, with the aim of helping practitioners improve athletes' outcomes. The Strength of Recommendation (SOR) Taxonomy was applied during open discussion among all authors to reach consensus on our recommendations related to clinical examination, rehabilitation interventions, and outcome measures. Collectively, this knowledge will inform the implementation of evidence-based rehabilitation interventions.

REHABILITATION

As soon as hamstring injury (HSI) has been confirmed, rehabilitation interventions aimed at preparing the athlete for a timely, safe, and effective return to sport (RTS) should be implemented without delay. In this section, we discuss the current evidence related to different exercise interventions and passive treatments used in HSI rehabilitation and considerations for their implementation.

Exercise Interventions

Progressive Running. A progressive return to high-speed running and sprinting is likely the

Key Points

- Mechanisms of hamstring strain injury likely involve a combination of high muscle-tendon unit forces (active or passive), extensive muscle-tendon unit lengthening beyond moderate lengths, and high-velocity movements.
- Returning to high-speed running is arguably the most important aspect of rehabilitation, given that it is fundamental to performance in many sports and a common mechanism for hamstring strain injury.
- Eccentric hamstring exercises and hip-extensor strengthening should also be implemented during rehabilitation to prepare athletes for the demands of high-speed running and address deficits in strength and muscle structure.

*This article appears courtesy of the National Athletic Trainer's Association (NATA.org). It was first available via Open Access in the February 2022 issue of the *Journal of Athletic Training.* References have been removed here for brevity, but the full list appears online. Part I appeared in the March 2022 issue of *Lower Extremity Review,* page 21-26.

Continued on page 25

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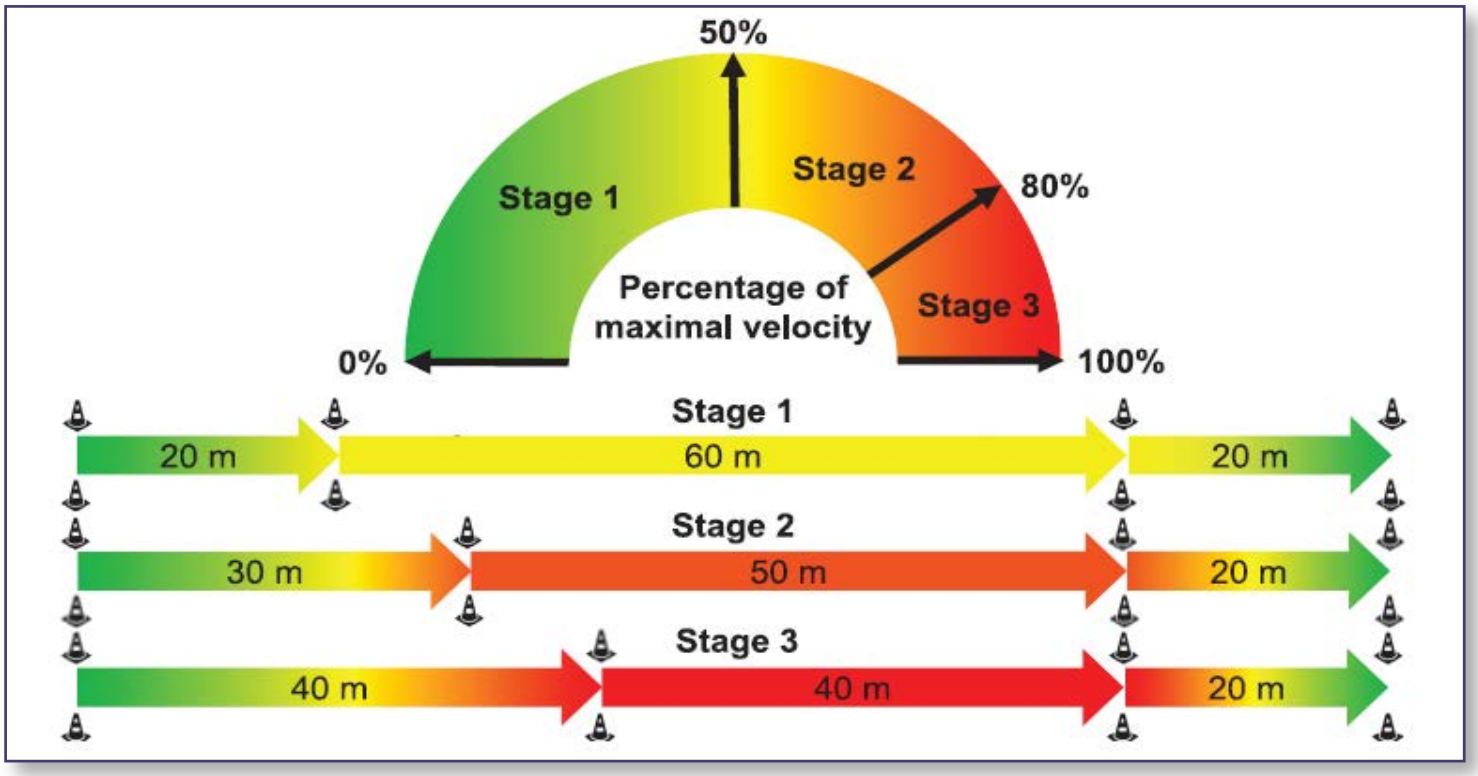

Figure 3. Example of 3-stage progressive running protocol over 100m, accounting for greater acceleration distances and more gradual intensity increases at higher percentages of maximal velocity.

most important aspect of rehabilitation, given that it is fundamental to performance in many sports and a common HSI mechanism. Figure 3 provides an example of a 3-stage progressive running protocol based on our collective clinical experience, understanding of biomechanical demands placed on the hamstring during running, and application of similar protocols in HSI rehabilitation. Stage 1 can be safely introduced after athletes can walk with minimal pain (eg, pain ≤4 on a numeric rating scale ranging from 0 to 10), progressing from a slow jog (approximately 25% of maximal velocity) to moderate-speed running (approximately 50% of maximal velocity) as tolerated. When moderate-speed running is tolerated, athletes can gradually progress through stage 2 but should only advance to stage 3 when high-speed running (approximately 80% of maximal velocity) can be performed without pain to minimize the HSI risk. During stage 3, progression toward maximal sprinting (100% of maximal velocity) should occur in relatively small increments (approximately 5%) to account for the substantial increase in negative (ie, eccentric) work required by the hamstring at running intensities >80% of maximal velocity.

When high-speed running and sprinting have been achieved, subsequent exposure during HSI rehabilitation and RTS should be individualized to the needs of each athlete. Where possible, large spikes in high-speed running volume should be avoided to reduce the subsequent HSI risk. The emergence and availability of wearable sensors (eg, global positioning systems, inertial measurement units) and other technologies (eg, timing gates, smartphone apps) make quantifying progressive running during HSI rehabilitation easier. Practitioners can use these approaches to gather outcome measures at RTS to objectively individualize running progressions, safely reintegrate athletes into regular training, and prepare them for sport performance. **SOR: A**

Eccentric Hamstring Exercises. Eccentric hamstring exercises are a common HSI rehabilitation intervention to prepare athletes for the demands of high-speed running and address deficits in strength and muscle structure. Emphasizing mainly eccentric actions and hamstring lengthening via the extender, diver, and glider exercises, the Askling L-protocol reduced RTS time compared with conventional and multifactorial interventions. However, none of the Askling L-protocol exercises load the hamstring to a high intensity during eccentric contractions, and high-intensity loading appears to be a key component of interventions proven to increase hamstring strength, lengthen long head of the biceps femoris muscle fascicles, and reduce the HSI risk. As deficits in hamstring strength and long head of the biceps femoris muscle fascicle length are seen after RTS, more progressive eccentric loading, such as the Nordic hamstring exercise (NHE), should be implemented during rehabilitation.

Although eccentric loading is frequently recommended as a rehabilitation intervention, the challenge for practitioners is knowing how and when to safely introduce exercises such as the NHE after HSI. Eccentric hamstring exercises are often avoided in the early stages of HSI rehabilitation and only introduced after pain and between-limbs strength deficits during isometric knee flexion have resolved. Nevertheless, eccentric loading can be safely progressed based on individual exercise performance, regardless of pain and between-limbs strength

Continued on page 26

Continued from page 25

deficits during isometric knee flexion after acute HSI. For example, the submaximal bilateral eccentric slider exercise can be introduced at the very start of HSI rehabilitation (Figure 4), and when athletes can perform this exercise through full range of motion (ROM), they can progress to a unilateral variation and begin the NHE (see Supplemental Video 1, available online at http://doi.org/10.4085/1062-6050-0707.20.S1). This progressive approach to eccentric loading has been shown to increase hamstring strength and long head of the biceps femoris muscle fascicle length in relatively brief periods of rehabilitation after acute HSI. Examples of these eccentric hamstring exercises and descriptions of when they should be introduced and progressed on an individual basis during HSI rehabilitation are provided in Figure 4 and Supplemental Video 1 (at https://doi.org/10.4085/1062-6050-0707.20). **SOR: A**

Hip-Extensor Strengthening. In addition to eccentric knee-flexor exercises, hip-extension exercises should be used to load the hamstring at longer muscle lengths. Submaximal exercises, such as the Askling diver, can be introduced at the start of HSI rehabilitation before progressing to hamstring bridges, 45-degree hip extensions, or Romanian deadlifts (see Supplemental Video 2 at http://doi.org/10.4085/1062-6050-0707.20). Apart from the hamstring, single-joint hip extensors, such as the gluteus maximus and adductor magnus, should be targeted if clinical examination shows weakness in these muscles, as they are key contributors to horizontal force production during sprint acceleration. These single joint muscles may be preferentially loaded over the injured hamstring during HSI rehabilitation by performing hip extension exercises with greater knee-flexion angles. Bilateral body-weight hip thrusts can be introduced at the onset of rehabilitation (Figure 4) and progressed to unilateral, loaded, and explosive variations (see Supplementary Video 3 at http://doi.org/10.4085/1062-6050-0707.20), which have been linked to increased hip-extensor strength and improved sprinting performance in uninjured athletes. Figure 4 and Supplemental videos 2 and 3 supply examples of these hip-extensor strengthening exercises

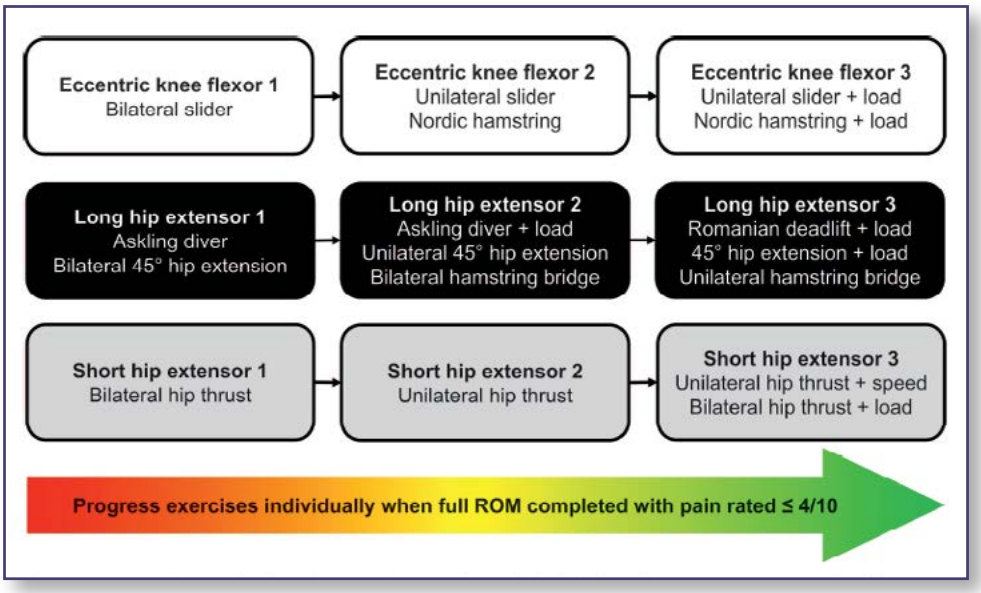

Figure 4. Example of progression of exercises targeting eccentric knee-flexion (white) and hip-extensor strength at long (black) and short (gray) hamstring muscle lengths. Abbreviation: ROM, range of motion.

and describe when they should be introduced and progressed on an individual basis during HSI rehabilitation. ***SOR: B***

Hamstring Flexibility Exercises. Exercises aimed at improving hamstring flexibility are regularly prescribed during rehabilitation to address deficits in hip-flexion and knee-extension ROM seen immediately after HSI. However, these acute ROM deficits typically recover within the first 2 weeks after HSI and may not require direct intervention. Yet hamstring flexibility exercises may be required if deficits persist during rehabilitation, as greater deficits in active knee-extension ROM at RTS have been associated with an increased risk of subsequent HSI. Recovery of active knee-extension ROM can be slightly accelerated by implementing passive hamstring stretching 4 times per day, compared with once daily, starting at 48 hours after HSI. Other hamstring flexibility exercises prescribed in HSI rehabilitation include supine active knee extensions and dynamic hamstring mobility exercises, although the effectiveness of these interventions is not clear. ***SOR: B***

Progressive Agility and Trunk Stability Exercises. Exercises proposed to improve agility and trunk stability came to prominence after they were shown to lead to fewer reinjuries versus a relatively conservative hamstring strengthening and stretching intervention during HSI rehabilitation. In a subsequent HSI rehabilitation study, RTS time and reinjury rates were no different between progressive agility and trunk stability (PATS) exercises and an intervention emphasizing progressive running and eccentric strengthening. The purported benefits of PATS exercises are that they promote controlled early loading through frontal-plane movements while avoiding end-range hamstring lengthening. It has also been argued that PATS exercises target other muscles of the lumbopelvic region, which could reduce the stretch placed on the hamstring during high-speed running, at least according to biomechanical models. Although these potential benefits have not been directly investigated after implementing PATS exercises, relative success in achieving timely RTS and acceptable rates of recurrence strengthens this otherwise theoretical rationale for their inclusion in HSI rehabilitation. ***SOR: B***

Running Technique Drills. Practitioners may implement running technique drills as tolerated during the early stages of HSI rehabilitation to replicate discrete phases of the sprinting gait cycle at reduced intensities and in a controlled environment. Running technique drills are perceived to reduce potentially unwanted movements, such as excessive anterior pelvic tilt, which is often linked to a risk of HSI because of increased hamstring length in this position.

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Some prospective evidence has shown an elevated HSI risk in athletes who sprint with greater anterior pelvic tilt and lateral trunk flexion or less gluteus maximus and trunk muscle activity. Yet, similar to PATS exercises, no direct evidence supports the use of technique drills to reduce HSI risk, improve running performance, or alter any other rehabilitation outcomes. Therefore, technique drills should be viewed as a nonessential accessory to progressive running that may be implemented if a sound clinical or performance-oriented rationale is provided. ***SOR: C***

Passive Treatments

Platelet-Rich Plasma (PRP) Injections. Some athletes may receive PRP injection therapy during HSI rehabilitation, depending on their access to resources and the practices of medical personnel involved in their management. Platelet-rich plasma injections have been suggested to enhance tissue healing and have been evaluated in the treatment of acute muscle injuries, with multiple studies including athletes with HSIs. In a recent meta-analysis, Seow et al showed no reduction in the RTS time or reinjury rate when PRP injections were added to exercise interventions during HSI rehabilitation. They also reported a lack of consensus on the timing, volume, and composition of PRP injections, and there is potential for resulting muscle soreness, which could affect exercise rehabilitation. Platelet-rich plasma injections appear, at best, to be a nonharmful yet ineffective treatment in accelerating RTS or mitigating the subsequent HSI risk. ***SOR: A***

Manual Therapy. Evidence endorsing manual therapy as a rehabilitation intervention after HSI is scarce. Acute increases in knee-flexor torque have been observed after sacroiliac-joint mobilizations were applied to individuals with a recent HSI, but these findings were limited by preintervention differences between those who did and those who did not receive this treatment. Lumbar spine facet-joint mobilizations and soft tissue massage were included in a multifactorial HSI rehabilitation algorithm; fewer reinjuries were noted but RTS was slightly prolonged compared with the Askling L-protocol exercise intervention. Mendiguchia et al did not assess outcomes often thought to be influenced by manual therapies (eg, pain or ROM), and the extensive nature of the rehabilitation algorithm made it difficult to know if these passive interventions were of any value. In the absence of clear evidence, practitioners need to consider the potential time cost of implementing manual therapies during HSI rehabilitation against any perceived benefit of these interventions. ***SOR: C***

Implementation Considerations

Implementing any rehabilitation intervention requires careful consideration of factors both intrinsic (eg, age and injury history) and extrinsic (eg, pressure to expedite RTS) to the athlete. Older athletes with a history of HSI or injuries to other areas may require longer rehabilitation times because of the need to address preexisting deficits and account for their increased risk of subsequent injury. Elite and professional athletes may be under more pressure to RTS, which can truncate HSI rehabilitation. Practitioners must consider these factors in various aspects of rehabilita-

tion in collaboration with coaches, the athlete, and other stakeholders in the shared RTS process.

As rehabilitation progresses to include more sport-specific training and high-speed running, it is important to avoid neglecting key exercise interventions. Complete cessation of eccentric hamstring exercise leads to shortening of long head of the biceps femoris muscle fascicles, which can be averted by continuing to perform these interventions, even at low training volumes. The effects of fatigue and muscle soreness must be considered when implementing both high-speed running and eccentric hamstring exercises. For example, eccentric hamstring exercises may cause fatigue and muscle soreness, which make high-speed running difficult during the subsequent 48 hours. The timing of these interventions may depend on the number of days an athlete can complete rehabilitation around other commitments. We advise that, if these interventions are prescribed for the same day, high-speed running should be performed before eccentric hamstring exercise to ensure that maximal sprinting is not compromised by fatigue or muscle soreness.

OUTCOME MEASURES

Throughout rehabilitation, follow-up clinical examinations and additional outcome measures should be used to monitor an athlete's recovery and inform the shared RTS decision-making process. In this section, we briefly cover pain, patient-reported outcomes, apprehension, and eccentric hamstring strength, along with assessment tools that can be used during HSI rehabilitation.

Pain

Rehabilitation is most commonly progressed after HSI when the athlete reports no pain during exercise, clinical examination, or functional tasks. A numeric pain rating scale (range = 0–10) can be used to evaluate the level of pain reported by the athlete. As opposed to the conventional practice of pain avoidance, allowing exercise in the presence of pain rated ≤4 on this scale during HSI rehabilitation is safe and may allow earlier exposure to and progression of beneficial stimuli. ***SOR: B***

Patient-Reported Outcomes

The importance of patient-reported outcomes is highlighted by findings that RTS prognosis was associated with self-predicted time to RTS and the number of days taken for the athlete to begin pain-free walking. In addition to asking the athlete these questions, practitioners can use the Functional Assessment Scale for Acute HSIs, a self-administered questionnaire, to assess the severity and effect of symptoms. Initial research into psychometric testing has shown this scale has good reliability and validity, but the minimal clinically important difference is unknown. ***SOR: B***

Apprehension

The Askling H-test can be used to evaluate an athlete's apprehension during rapid hamstring lengthening by performing explosive unilateral hip flexion with the knee fixed in extension by a brace. An electric goni-

Continued on page 31

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ometer can also be used to quantify hip-flexion ROM during the Askling H-test, which may identify deficits that are otherwise undetected via clinical examinations of hamstring flexibility during the later stages of HSI rehabilitation. Implementing the Askling H-test as a final RTS criterion is associated with a low risk of reinjury but prolonged HSI rehabilitation time, and practitioners may need to consider which outcome is a higher priority for each athlete. ***SOR: B***

Eccentric Hamstring Strength

Depending on resources, eccentric hamstring strength can be objectively tested using several tools, including isokinetic dynamometry and handheld dynamometry, or during the NHE using externally fixed load cells. The evidence for eccentric hamstring strength as a risk factor for HSI is conflicting, and asymmetries after RTS were not associated with reinjury. Eccentric hamstring strength is associated with sprint acceleration mechanics, which are important for performance in running-based sports. Therefore, maximizing eccentric hamstring strength and relative between-limbs symmetry is currently considered a desirable rehabilitation outcome for sports performance but not an essential RTS criteria to reduce the reinjury risk. ***SOR: B***

FUTURE DIRECTIONS FOR PRACTITIONERS AND RESEARCHERS

Despite the proliferation of HSI research in recent times, key questions related to improving rehabilitation outcomes for athletes remain unanswered. In this section, we identify 2 key questions for both practitioners and researchers to consider in shaping the future directions of HSI rehabilitation.

Are There Key Rehabilitation Interventions or Is a Multifactorial Approach Essential?

The concept of multifactorial rehabilitation is logical, given the plethora of known and potential contributors to HSI risk and athletic performance. Implementing multiple intervention types increases the likelihood of reducing the HSI risk and improving athlete performance but requires more time to implement during rehabilitation, which could delay RTS. Practitioners dealing with time constraints need to prioritize rehabilitation interventions that actively contribute to improved outcomes for athletes over those that may add little benefit. However, it can be difficult to identify the most effective interventions when these are implemented as just one part of a multifactorial approach to rehabilitation. In the future, researchers need to better delineate the individual components of HSI rehabilitation to identify key interventions and their minimum effective dosage to improve outcomes for athletes.

Unfortunately for practitioners, many interventions still lack an evidence base to support or refute their implementation during HSI rehabilitation. Still, the absence of evidence does not necessarily equate to the evidence of absence. In these cases, practitioners need to carefully apply critical thinking and consider a sound rationale for why a proposed intervention may improve HSI rehabilitation outcomes. For example, direct evidence may not demonstrate that a certain intervention improves outcomes when implemented during HSI rehabilitation. Instead, evidence from uninjured athletes may indicate that an intervention leads to desirable adaptations, which is presumed to lead to improved rehabilitation outcomes.

Can We Assess The Reinjury Risk at Return to Sport?

Another challenge of HSI rehabilitation is uncertainty regarding which modifiable variables, if any, are associated with the reinjury risk when assessed at RTS. Deficits in hamstring muscle structure and function have been observed at the time of RTS or even later after HSI, but currently little evidence addresses whether these variables are associated with reinjury. When measured at RTS, the risk of reinjury increased with greater between-limbs deficits in active knee-extension ROM and isometric hamstring strength but was unaltered by residual deficits on MRI scans or isokinetic strength. These results were limited to relatively small sample sizes, highlighting the need to conduct multisite studies and use a standard suite of RTS assessments over several years to identify variables associated with the reinjury risk.

Until this research is conducted, practitioners must be cognizant of the limited evidence available and employ a pragmatic, heuristic approach that considers the need for athletes to be able to (1) exceed preinjury levels (if these data exist) in variables thought to be factors contributing to the initial injury (eg, long head of the biceps femoris muscle fascicle length), (2) allow for the resolution of between-limbs asymmetry that arises in response to the pathology (eg, ROM and strength asymmetry), and (3) ensure sufficient exposure to key variables required to maximize performance at RTS (eg, high-speed running). Although a clear consensus related to RTS is lacking, resolution of pain, symmetry (<10%–15% asymmetry) with ROM and strength testing, completion of on-field performance and functional testing, and confirmed psychological readiness are the most pragmatic variables for practitioners to take into account. Furthermore, it is widely accepted that the RTS process should involve shared decision making among the player, team medical staff (physicians, athletic trainers, physical therapists), and strength and performance staffs.

For the annotated version with references, please see online at lermagazine.com. ler

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Lymphatic Immunopathy and Its Importance in Chronic Wound Healing

By James McGuire, DPM; Avnee Jiten Patel, BS; and Ron Michael Adduru, BSN

Untreated lymphedema can play a significant role in chronic wounds. Manual Lymph Drainage (MLD), performed by a Certified Lymphedema Therapist (CLT) is standard of care for the management of lymphedema of all types, not just advanced disease.

A coordinated immune response to illness, in particular, chronic wound healing, depends on the efficient functioning of the arterial, venous, and lymphatic systems. The lymphatic component of the vascular system in chronic wound healing has received little attention in protocols and guidelines designed to address barriers to healing. Traditionally, the lymphatic system has been thought to function as a passive regulator in our systemic immune response by transporting antigenic cells, materials, and immunologic mediators to regional lymph nodes. Damage to or alteration of the free flow of lymph through local or regional lymphatic vessels in the area of a chronic wound contributes to pathological changes to the lymphatic system that results in a delayed immune response referred to as "lymphatic immunopathy" or what J.A. Carlson referred to as microlymphedema.[1]

The lymphatic system has been shown to play 2 roles in facilitating an immune response. On a micro level, lymphatic endothelial cells (LECs) regulate immune responses by directly modulating the entry of immune cells into lymphatic capillaries, presenting antigens on major histocompatibility complex proteins, and modulating antigen-presenting cells (APCs).[2] On a macro level, the lymphatic fluid flow transports these to regional and central lymph nodes where an immune response is generated. Local edema and tissue scarring in response to chronic inflammation associated with wound chronicity leads to decreases in both micro and macro activity and leads to the development of a "lymphatic immunopathy."

Lymphatic micro-mechanisms involve cellular-level regulation of immune responses. Immune cell entry, migration of LEC cytokines and chemokines through the lymphatic system, and adhesion molecule expression are a few of the chemical modulations promoted by a functioning lymphatic system. The balance of T-cell inflammation is integral to mitigating fibrosis. CD4 cell differentiation into T-helper 1 (Th1) cells increases the activity of Interferon gamma (IFNγ) which is largely anti-fibrotic versus T-helper 2 (Th2) cells which play a pro-fibrotic role.[3] This cycle of T-cell inflammation involving downregulation of CD4+ cell and upregulation of Th2 differentiation leads to lymphatic vessel fibrosis which contributes to lymphedema, a chronic tissue swelling caused by the overwhelming of the lymphatic system.[4] Dendritic cells, powerful leukocyte APCs which regulate T-cell responses, upregulate expression of the chemokine cell surface receptor CCR7 whose ligands are expressed by LEC cytokines.[2,5] CCR7 ligand gradients guide dendritic cells to the initial lymphatics facilitating entry into the vessel lumen.[2,6,7] This activation precedes the chronic cycle of CD4+-mediated inflammation which damages the free flow of fluid through the lymphatic system physically preventing a rapid immune response to bacteria, viruses, and fungal invaders; the efficient removal of accumulated waste products from the tissues; and leads to local or periwound edema or, if extensive, a regional clinical presentation of lymphedema.

"Immune Ignorance"

If the lymphatic system is blocked, the immune system is unaware of an inflammatory process occurring in the afferent tissue and remains unengaged, resulting in immune ignorance.[8,9] IFNγ inhibits differentiation of naive T-cells to Th2 cells, serving as a pro-inflammatory, anti-fibrotic cytokine.[3] When the influence of IFNγ is weak, the natural killer T-cells produce IL-4 without being affected by dendritic cells. IL-4 causes naive T-cells to differentiate into Th2 cells which promote chronic inflammation with the help of

Continued on page 34

Continued from page 33

M2 macrophages which promote tissue fibrosis.[8] The imbalance of differentiation between Th1 and Th2 is significantly increased in lymphedema. Differentiation of Th1 cells is suppressed in lymphedema, which renders the host prone to severe infection and may cause depression of wound healing activation. In addition, intensive differentiation of Th2 cells causes progression of fibrosis, also leading to disruption of the wound healing process.[8] By this mechanism, the immune regulation of the lymphatic system on a micro-scale can manifest itself on a macro-scale.

On a macro-level, the lymphatic system, via lymphatic vessel tone and lymphangion contraction, regulates immune responses by modulating the rate at which extracellular fluid is returned to the vascular system, and antigens and pathologic cells are delivered to regional lymph nodes.[2,10-13] Injury to the lymphatic system resulting from direct trauma to the vessels, or a prolonged inflammatory or insufficient reparative process results in blockage of the lymphatic system. Primary or hereditary causes of lymphedema include congenital lymphedema, lymphedema praecox, and lymphedema tarda. Secondary lymphedema causes include: traumatic injury, iatrogenic, oncogenic, or infectious damage to the lymphatic vessels. For the purpose of this paper, we will limit our discussion to secondary lymphedema which may present as a local, regional, or systemic blockage depending on the extent of lymphatic injury.

Lymphostatic Dermopathy

As previously discussed, a wound can lead to a local lymphatic immunopathy with dysfunction of chemical modulators leading to a prolonged inflammatory response, tissue breakdown, and loss of dermal integrity. Lymphostatic dermopathy, or failure of immune function of the skin, contributes to all wounds and skin dysfunction and can even lead to expansion of the wound.[1] Primary dermal breakdown from underlying circulatory system failure can be called dermal disruption ulceration and presents as small coalescent ulcerations that quickly expand and form larger more obvious wounds if not addressed. This vascular injury presents as lymphatic vessel lumen enlargement, valve dysfunction, and loss of smooth muscle cell coverage. If this inflammatory process is prolonged, it promotes interstitial fluid retention and tissue edema, followed by tissue fibrosis and adipose deposition.[14]

The cascade of immune responses leads to physical degenerative changes to the lymphatic system. At a macro-level, the fibrosis related to collagen deposition causes stasis and increased fluid accumulation in the lymphatic system. Immunologically, this results in stagnation of immune cells surrounding the area of blockage while the inflammatory cells accumulate within the area. Clinically, this may present as a lymphatic dermopathy. The ability to heal wounds is significantly decreased and the risk of developing wounds significantly increased when this inflammatory cycle becomes chronic.

A thorough understanding of how the lymphatic system functions is critical to improve wound healing outcomes. Most chronic non-healing wounds observed in podiatric wound care have been complicated by obesity, diabetes, and uncontrolled lymphedema. Wound healing is affected

by lymphedema both pathophysiologically and immunologically. The pathophysiological effects result from impaired tissue remodeling due to excessive accumulation of interstitial fluid, microvascular ischemia caused by internal tissue pressure, and cell damage by accumulation of cell debris. The immunological effects of lymphedema contribute to immunodeficiency and chronic inflammation of wounds.[8,15]

To Promote a Healing Environment

An understanding of the underlying immune response is integral to the treatment of wounds. To create an environment that promotes wound healing and epithelialization, the underlying edema must be recognized, and treatment modalities utilized to address this fluid stagnation. Edema is generally classified as being high-protein or low-protein. Lymphedema is a high-protein edema which results from damage to or the absence of a normal lymphatic system. Proteins are deposited in the interstitial tissues when lymphatic capillaries are unable to transport them back into the venous system resulting in a change in osmotic and hydrostatic pressure. The change in interstitial pressure attracts more water into the interstitial tissue alongside the trapped proteins leading to fibrosis and edema. Unlike lymphedema, venous insufficiency is initially a low-protein edema characterized by an accumulation of water not resulting in tissue fibrosis. Chronic venous insufficiency causes high filtration pressure and increased fluid in the tissue leading to venous hypertension and an increased lymphatic water load. When either the venous or lymphatic system is overburdened, it can lead to fatigue of the other system.

Most wounds which develop in edematous legs have venous insufficiency as a primary initial cause which leads to secondary phlebolymphedema, the major cause of lymphedema in the US.[16] Phlebolymphedema develops from longstanding venous insufficiency which frequently is inadequately addressed in its early stages and allowed to progress without compression or other simple interventions such as weight loss, elevation, and exercise. When both the venous and lymphatic systems are overwhelmed, a lymphatic overload occurs. Activation of inflammatory cytokines results in an influx of inflammatory cells, a change from a watery transudative edema to a protein-rich exudative edema, and a local lymphatic immunopathy. Inflammatory skin changes and skin breakdown lead to ulceration and delayed healing when the developing immunopathy is left unaddressed.[17,18] In many ways, the progression of skin changes seen reflected in the categories of the CEAP classification are a measure of the degree of lymphatic immunopathy present in the tissues and what leads to ulceration and poor healing.[19]

Recent research supports the treatment of lymphedema with complete decongestive therapy, including manual lymph drainage, graduated compression garments, lymphedema wraps, therapeutic exercises, meticulous skin care, and the addition of intermittent pneumatic compression.[20] The combination of these treatments promotes fluid return from interstitial tissues to the vascular space and mobilizes immune cells from the area of

Continued on page 36

Continued from page 35

blockage, which reduces swelling and eliminates the static immunopathy associated with lymphedema.

Compressive treatments are used for both venous mediated and lymphatic edema. Compressive devices include single- or multi-layer elastic or inelastic short or long stretch bandages, stockings, Velcro™ closure systems, or several types of segmental compression pumps. Compression can also be classified as either passive or active. Passive systems include most wraps and bandages; active systems include various intermittent pneumatic compression devices designed for venous or lymphatic edema. Dressings containing elastic or long stretch components are able to function in both ambulatory and non-ambulatory conditions while short stretch dressings function best in patients who are ambulatory.[21] Manual Lymph Drainage (MLD) performed by a Certified Lymphedema Therapist (CLT) is standard of care for the management of lymphedema of all types, not just advanced disease. Segmental devices attempt to use sequential application of compressive forces to move venous blood and low protein transudate from surface vessels to deeper ones. Multiple chambered light pressure lymphatic pumps are used to facilitate movement of exudative lymphatic fluid through existing open lymphatic channels to larger more proximal lymphatic vessels.[22]

Too often patients are referred only after symptoms of skin breakdown and edema have reached significant levels. Rarely are CLTs used for periwound microedema or phlebolymphedema which would significantly improve healing of chronic wounds. Unaddressed lymphostatic microlyphedema leads to the development of a wider periwound lymphostatic dermopathy, or skin failure.[20] For many of the chronic wounds we treat, this mechanism is why they fail to heal or expand in size during our initial therapies. In combination with advanced wound healing, complete decongestive therapy, and edema mitigating technologies, counseling patients on the importance of early intervention with exercise, diet, and compressive hosiery could prove invaluable to improving both the quality and efficiency of our attempts at wound healing.

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CLINICAL PERSPECTIVE: ON SITTING

How to Improve Sitting Posture of Individuals with Disabilities and Others

By Dalia Zwick, PT, PhD

It is well understood that the feet are the foundation of the body when standing. But even in a seated position, the feet play a foundational role in the body's support, balance, and posture.

Think about what a chair does: Galen Cranz, PhD, an architect and Alexander Technique (a system of body-mind postural education) practitioner, published a book called *The Chair: Rethinking Culture, Body, and Design*, where she explores challenges in chair design. Should the angle of a chair be flat, tilted backward to stop forward slide, or tipped forward to prevent sacral seating? How high should the chair be to serve both tall and short people? Should chairs have a back for trunk and lumbar support? She concludes that decisions made about any one of these factors affect all of the others.[1] Her main message is that people who can move freely need to be encouraged to frequently change position and posture to improve their well-being while seated.

But what about people who have difficulty moving and changing positions, and those with disabilities who have difficulty maintaining a sitting posture? And what about people who may not be aware that they sit in awkward positions that may, in the long run, hurt their bodies?

The focus of this article is on how physical therapists and other healthcare professionals can help improve comfort and body posture in sitting, with a focus on the position of the feet.

Pauline Pope, FCSP, BA, MSc, SRP, a UK physiotherapist who has years of experience working with individuals with complex disabilities and body shape challenges, distinguishes between good and bad posture. She explains that a bad posture is one that causes damage to the body; however, she also adds that any posture has the potential to cause damage if not relieved or changed when the sensory signal from stressed tissue is ignored. Pope further states that an ideal "good" posture allows for effective functional performance, is energy efficient, and does not damage the body.[2]

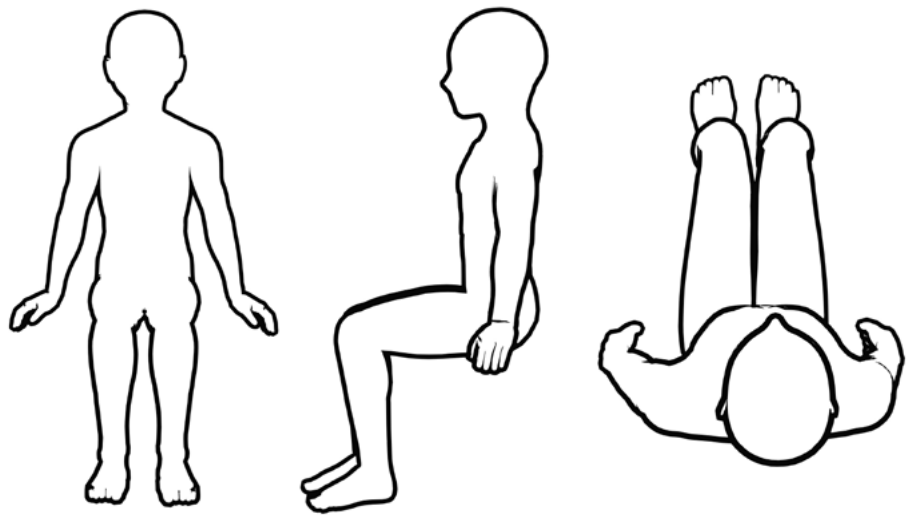

Figure 1. Normal sitting posture with proper pelvis alignment: (from left to right) frontal, side, and top views.

It is also important to distinguish between posture as a structure; posture ability, which is the ability to get in and out of posture; and posture control, which is about balance. When we describe posture, we give information on how the body as a structure is aligned or arranged at a given moment. The focus of this article is not on posture control or balance, but on the body structure in terms of range of motion, alignment, and symmetry. For able-bodied people and those with disabilities, the ability to control, change, and adjust posture depends on the supporting surface and internal and external force disturbances in balancing the body. When the body moves voluntarily, it needs to have an anchor or fixed point, such as the feet or the pelvis, that the muscles can rely on like a closed chain.

How We Sit

Sitting with feet planted on the floor is key in balance control and posture alignment (Figure 1). One should observe the feet when checking the sitting posture of the patient as foot posture in a semi weight bearing position such as sitting may help to observe foot distortion when present. Observing patients while sitting, one may find that their pelvis may be tilted backward and their knees turned out, abducted, and externally rotated (Figure 2). It is important to understand that this habitual sitting will affect the posture of the foot and ankle. This can even be translated into standing. It is suggested that, when sitting, patients are educated so they know to align their pelvis so they are sitting directly on their ischial tuberosities, their legs (at knee level) forward in line with the sagittal plane, and to align their feet with their big toe pointing forward and longitudinal arch raised. Observing the habitual posture can help in assessment, and asking the patient to improve and realign their posture can offer an opening for patient education. Podiatrists and therapists who treat feet impairments can help their patients by sharing with them some

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pointers on how to pay attention to and improve their posture while sitting.

The way we sit depends on our postural habits as well as anatomical and physiological constraints. Sitting posture is often influenced by ability, cultural habits, and sensory awareness combined with knowledge, or lack thereof, of proper posture. It is also influenced by what type of surface one sits on. For example, a lifetime of sitting unsupported on the floor develops muscle and joint flexibility required for floor- and chair-sitting, however, a lifetime of habitual chair sitting lacks the muscle and joint flexibility for floor-sitting. This, and the fact that cross-legged positions are also beneficial to chair-sitting, contributes to why people in India regularly sit on train seats and waiting-room benches in the cross-legged position—they find this way of sitting more comfortable than sitting on chairs,[3] and why, in the West, people unaccustomed to sitting cross-legged rapidly become uncomfortable in such a position.

Sitting posture depends upon more than just the chair type. In sitting, the pelvis either slouches backward (Figure 3A), plants itself firmly in the middle (Figure 3B), or rocks slightly forward (Figure 3C), thus influencing the spine above and the joints of legs below. Sitting posture is also affected by the chair design, specifically the seat-back angle, seat-bottom angle, foam density, height above floor, and presence, or lack thereof, of armrests. An example of a good seat height at work or in a study environment is when computers or monitors are at eye level. Forward-tilting, seat-bottom inclines can increase pelvis forward rotation, which increases lordosis. However, people who already possess optimal physical ability reports this posture as the most comfortable and practical. The best ratings overall are given to adjustable chairs that allow changes in position—most notably, with feet planted firmly on the floor or on a foot stool of some type.[4]

Disability and Sitting

Stability of posture is a perquisite to movement. As a physical therapist, I observe how people with different levels of physical ability sit and how they adjust their body posture while they reach, move, or relieve themselves from sensory overload. Purposeful movement, such as reaching, can be initiated only when stability of body posture is achieved.[5]

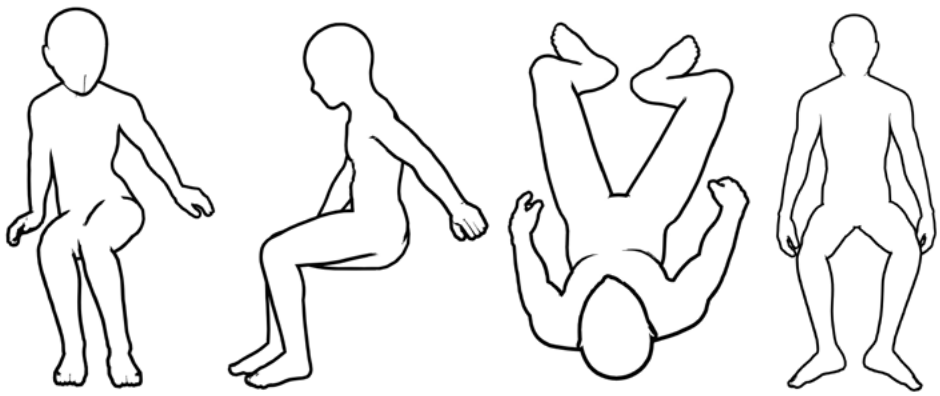

Figure 2. Abnormal sitting posture (from left to right) front and side; top view of abnormal sitting posture with knees turned out, abduction, and external rotation of the hips

To be engaged in movement, the posture of the body needs to be well aligned, balanced, and stable on the surface. To expand on what Pope states regarding good sitting posture, we will use the term explained by Zollars as "neutral posture," which describes when the person's pelvis is upright and level, the trunk is symmetrical and elongated, and the hips, knees, and ankles are in a good alignment.[6] However, a neutral posture in sitting varies from one person to another depending on a variety of constraints.

I work with adults with disabilities who have difficulty maintaining their sitting posture due to weakness, reflex influence, and limitations in the range of motion and flexibility in their joints and muscles. This is a contributing factor to many of the individuals having body distortions such as scoliosis, pelvic malalignment, and rotation deviation of the knees to one side (windswept distortion). Many of these individuals often require adaptive seating to maintain their posture. Creating an adapted seating system is an important support to the body when body shape distortions are present. Some people with disabilities who use wheelchairs often sit as many as 14 hours a day in one position.

Therefore, a look at the bigger picture, is needed to help improve comfort, flexibility, and ability of the individual to stay in a sitting posture. Caregivers and therapists need to recognize, understand, and help suit the needs of individuals with disabilities to change their position in sitting. Even just taking the individuals out of the chair and into a supine position with support, and slightly altering the position of the legs can make a huge difference! There is also a need to focus on improving flexibility in joints, muscles, and other connective tissues during therapy sessions. Improving flexibility will improve muscle efficiency of posture so that the necessary long duration sitting can be endured. This can be done in therapy sessions, during which, in addition to working on improving flexibility, the individual's body should be placed and supported in a supine position as to simulate sitting positions. In other words, instead of attempting to work against gravity, as one does in sitting, gravity is being used to our advantage.

Yoga and Sitting

As a long-time Iyengar yoga practitioner, I practice what is called yoga-asanas, or poses (positions). Iyengar yoga is known for its focus on alignment and its use of props, or external objects, to support the body. By using these props, individuals can engage in poses that would otherwise be more difficult.[7] In Iyengar yoga, individuals are supported in poses for varying amounts of time, as opposed to other yoga styles, where practitioners move rapidly in and out of poses.

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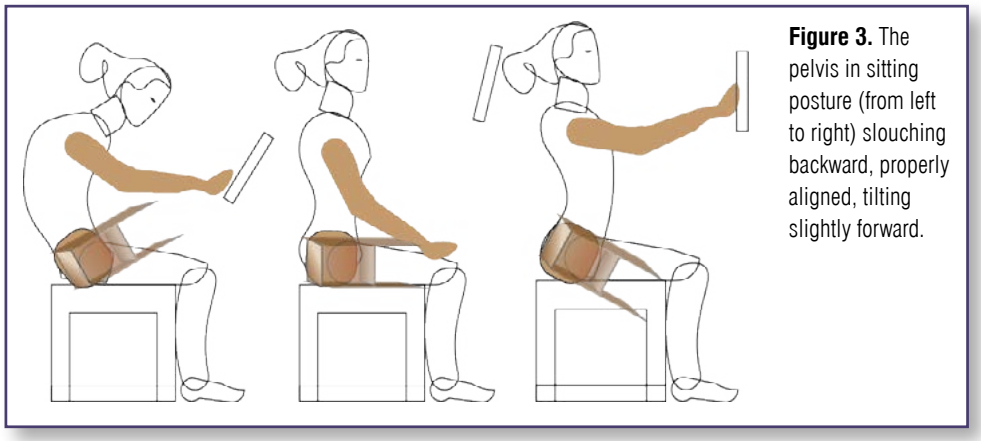

Figure 3. The pelvis in sitting posture (from left to right) slouching backward, properly aligned, tilting slightly forward.

The aim of yoga-asanas is to help improve the ability to sit with ease for extended periods of time. This is particularly important while practicing the poses of breathing, pranayama, and meditation, as this was traditionally the aim of practicing yoga. Posture is defined in the old Yoga Sutras as "steadiness and ease."[8] The root of the word asana is "as," meaning to sit.[9] I integrate tenets and principles of yoga and therapy when working with individuals with disabilities.

I use yoga positioning based on Iyengar yoga principles to improve the range and flexibility of muscles and joints. Practicing this approach during therapy requires the use of props to support various body positions. Placing an individual into supine lying for example, a pose that in yoga is similar to a supported version of Dandasana, involves assisting the patient in supine by positioning their legs so they are supported by a bolster or a chair, simulating sitting (Figure 4). By doing this, we are trying to achieve an angle of 90 degrees at the hips and knees. Here, similar to our previously mentioned "neutral position" in sitting, the pelvis needs special attention, as it needs to be posteriorly tilted and leveled, and the trunk should be symmetrical and elongated, with the hips, knees, and ankles in good alignment. Support is also provided with a belt, which is especially important when influence of tone or reflex is present.

Therapy and Sitting

The position of the feet in sitting greatly contributes to the stability of the pose. The base of support in the sagittal plane is significantly greater when one sits with the feet planted on the floor as opposed to when one sits without the feet touching the floor.[10] When sitting with the feet in contact with the floor, the base of support extends from the toes (the front of the base) to the rearmost end of the buttocks (the end of the base) where it contacts the seat.[11] In the presence of disability, we often observe foot deformities in those who use wheelchairs, partly because the individual does not bear weight on them. This should be attended to in therapy.

According to a study of sitting and standing performance, 52% of children with cerebral palsy (CP) use standard chairs and 42% use

Continued on page 45

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adaptive seating.[11] The fact that these children with disabilities use standard chairs does not necessarily mean that the chair is suited for them or that they find the chairs comfortable. It is observed that individuals with developmental disabilities often develop contractures of muscles, which causes stiffness, around the hips. This hip stiffness can limit one or both hips' mobility and flexibility, making sitting a challenge. Frequently, a condition described as asymmetrical limited hip flexion (ALHF) is present. This condition makes it even more difficult to sit comfortably, as most standard chairs require 90 degrees of hip flexion, or mobility. This hip asymmetry shows an association between an asymmetrical trunk, an uneven weight distribution, scoliosis, and a windswept hip distortion.[12] This can be explained by the fact that the pelvis is the anatomical structure that is directly linked to the hip joint, and can therefore be expected to be most affected when hip flexion is less than 90 degrees in the sitting position.[6] These distortions and limited ranges at the hip, pelvis, and trunk always necessitate the adapted seating surface and specialized wheelchair, preferably with a tilt mechanism.

The concern I have with special seating is that individuals with severe distortions and individuals who are older are frequently treated while they are still in their wheelchair. Reasons for this can include time limitations, a lack of transfer equipment, and the often-incorrect assumption that patients cannot be provided with any better sitting environment than their adapted seat in the wheelchair. An approach and focus in therapy should be on improving posture and ranges of motion as previously described. Studies show that bone/joint complications (eg, hip displacement, range of motion, windswept posture, scoliosis) had the strongest direct pathway with pain in the lower extremities, followed by reduced mobility in children and adolescents with CP.[13] This pain can be reduced through thoughtful therapy, a combination of attending to the patient's specific needs and the patient's specific limitations.

The main point we can take from these studies is that when sitting, the pelvis should be supported to stay in an upright position where the 2 ischial tuberosities are supporting the body weight equally. The feet should be in a good position, planted on the ground or some other supporting surface such as a foot plate if a wheelchair is used. If this position cannot be achieved, the body needs to be supported. ler

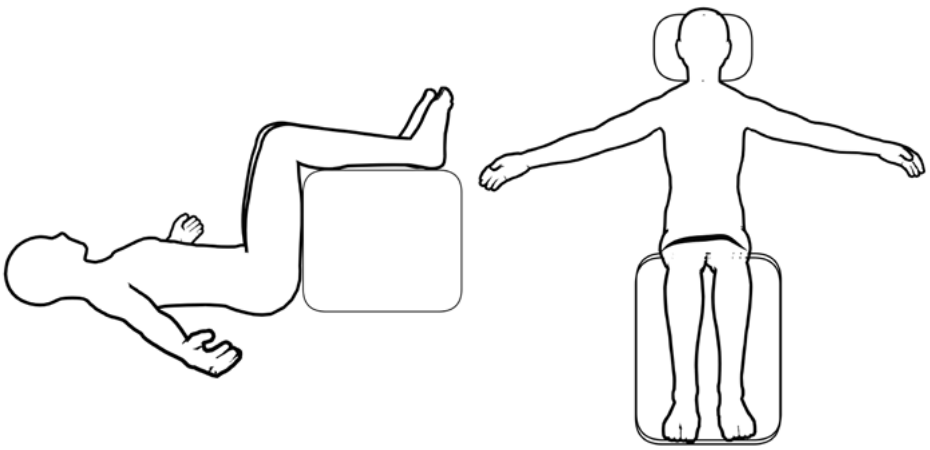

Figure 4. Supine lying yoga pose with prop support side and top views.

Dalia Zwick, PT, PhD, is a senior rehabilitation supervisor working part-time managing foot and ankle services at clinics for people with disabilities in New York City.

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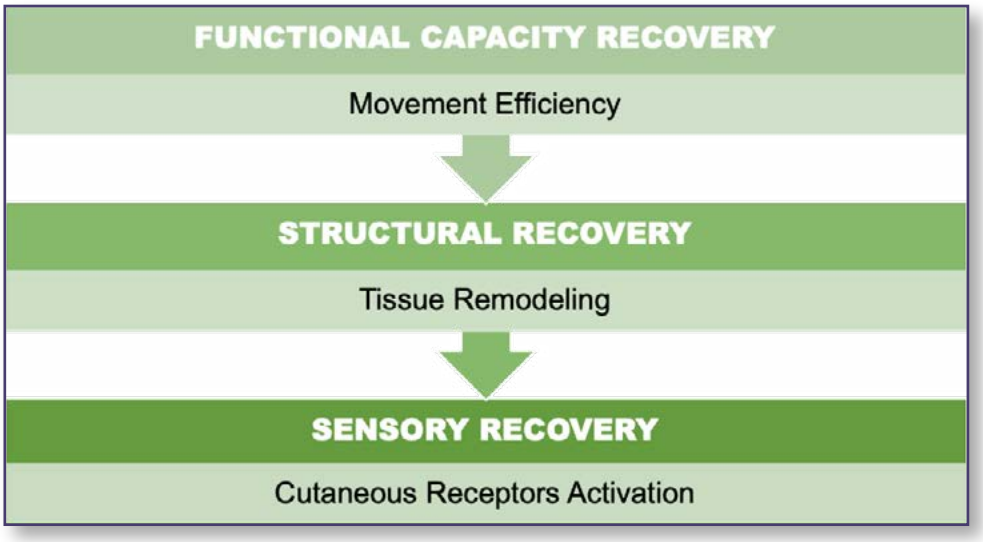
Recovery and Regeneration Strategies for Foot Performance Part 3

By Antonio Robustelli, MSc, CSCS

In the first article[1] of this series, I introduced the concepts of recovery and regeneration as well as terminological and methodological differences; in the second article,[2] I discussed the main aspects related to the 3 levels of foot recovery (Functional, Structural, and Sensory).

In this third and last article, I will focus on the pratical approach by translating the concepts into a sample protocol that can be used to target the recovery and regeneration of the foot/ankle complex.



Foot Recovery Protocol

1.) Functional Capacity Recovery

Timing: Immediately at the end of the training session

Duration: 4 minutes

Mode: Movement of the foot/ankle in different directions and planes with the assistance of electrical muscle stimulation. If using a DC current device (ie, Neubie [NeuPT Technologies, Tampa, FL]), it is possible to apply the stimulation during the whole period of movement; if using a traditional AC current device (ie, Compex [Enovis {formerly DJO Global}, Carlsbad, CA], MarcPro [Huntington Beach, CA], Powerdot [Therabody, Los Angeles, CA]), you can alternate between 40 seconds of stimulation at low frequency (less than 20 Hz) and 60 seconds of active movement. Pads should be placed on calves and soles of the feet.

a.) Calf raises in a slow and controlled fashion for 60 seconds

b.) Dorsiflexion and plantar flexion non-weight bearing in a slow and controlled fashion for 60 seconds

c.) Inversion and eversion weight bearing in a slow and controlled fashion for 60 seconds

d.) Toe flexion and extension in a slow and controlled fashion for 60 seconds

Goal: Starting the recovery process by facilitating the restoration of movement efficiency, the mobilization of fluid wastes, and a shift into parasympathetic mode.

2.) Structural Recovery

Timing: From 6 to 24 hours after the training session

Duration: 10-15 minutes

Mode: Mechanical decompression with devices providing negative pressure (ie, LymphaTouch)

a.) Stationary technique with LymphaTouch on calf muscles and plantar fascia (the technique involves holding the treatment cup on specific muscles and areas for 3 to 5 pulsations).

Pressure settings: 260-290 mmHg

b.) Sliding technique with LymphaTouch on calf muscles and plantar fascia (involves the sliding of the treatment cup over the desired muscles and areas).

Pressure settings: 290-330 mmHg

Goal: To promote regeneration and to avoid overuse and chronic damage, to improve the tolerance ability of tissues to handle mechanical stresses as well as to accelerate the remodeling process.

3.) Sensory Recovery

Timing: Before sleep at the end of the training session day

Duration: 15 minutes

Mode: Foot bath with Epsom salt (temperature 40°-45° C/104°-113° F) and topical skin applications with essential oils and extracts (maca root and flower).

Goal: Regenerate the skin and amplify the sensory activation.

Antonio Robustelli is a professional sports performance consultant and elite coach from Italy. He is also a member of the LER Editorial Advisory Board and can be reached at Antonio.Robustelli@omni-athlete.com.

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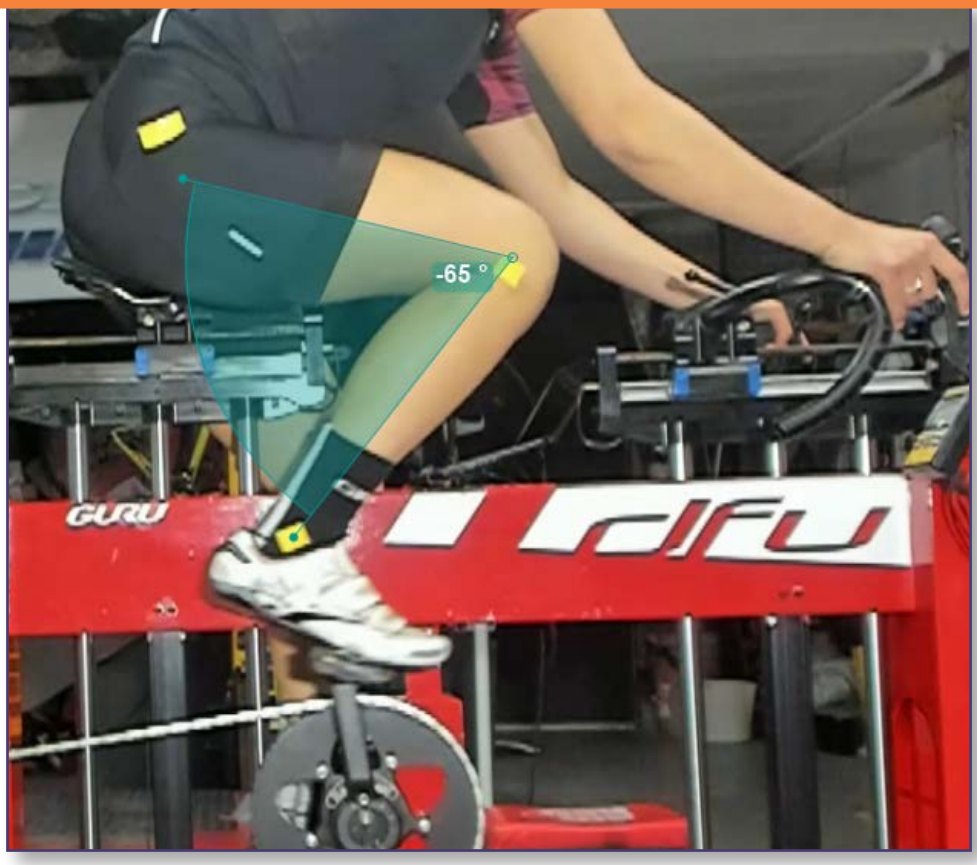
The Future of Bike Fit (Part 2) – Interview of the Bike Fit Machine Manufacturers and Bike Fit Education Content Creators

By Rick Schultz, DBA

In the September 2021 issue of *Lower Extremity Review*, Happy Freedman wrote an article titled "The Future of Bike Fit," in which several bike fitters were asked their opinions about the future of bike fitting. But what about the opinions of the bike fitting machine manufacturers and the bike fitting educational course creators?

I recently discussed bike fitting, including future predictions as they relate to everyday consumers (vs pro cyclists), to just such a group of professionals: Niels Boon of Shimano Experience Center's bikefitting.com; Eric Bjorling, with Trek Bicycle's Precision Fit system; Scott Stroot, Specialized's Retul & Body Geometry business and marketing manager; Andy Brook, president of the International Bike Fitting Institute (IBFI); William Thomas, CPT, CSCS, a California State Time Trial (TT) champion, exercise physiologist/kinesiology faculty at California State University Fullerton, sports nutritionist, and cycling coach; and Amy Schultz, PT, DPT, CSCS, who, in addition to being a board certified physical therapist with Red Bull, is a certified sports trainer, certified bike fitter, and former cat 2 women's bicycle racer.

With respect to where bike fitting was in the past compared to where it is now, Boon outlined advances in technology and healthcare. "I think the reasons why pro cyclists are retiring later is not just related to bike fitting, but rather to a better overall way of keeping riders fit for their job (nutrition, training science, medical care, etc.). But the main improvement in bike fitting is the inclusion of modern technologies like faster CPUs in computers, which can handle more complicated algorithms; 3D motion analysis technology; and power meters with 3D force vector measurements," he said, adding that these same advances are available for the masses as well.



Brook agreed about the importance of the medical and physiological aspect of training and added that bike fitting has also played a part in that shift but to a lesser capacity. "Riders used to race all year, across all kinds of events, but now they better understand training load and recovery," he said. "Don't get me wrong, bike fitting has definitely reduced the risk of overuse injuries, so it's played a part, but I think the training knowledge played a bigger role."

These are great points. Better nutrition pre-, during, and post-race, better training science, and better medical care also play an important role in prolonging the pro cyclists' career, with bike fitting being a part of it and becoming ever more available on a wider basis, to the everyday consumer, as Boon pointed out.

Going Mainstream

"I see bike fitting heading to a more mainstream service that is offered by bike stores as a way to keep driving/attracting consumers into their physical premises," Boon said. "We also hope to see that the translation of results from a bike fitting to the 'real' or outside environment of the cyclist will improve and that it will become the norm to do a bike fit (of whichever level, basic or advanced) with every bike sold. Automation will have its place to predict 80% to 90% of the fit. But for the last 10% to 20% (and from a comfort/performance point of view, very important), a trained bike fitter will always be necessary."

Reading between the lines, Boon is throwing bike sizing into this equation as well. The correct size bike is often overlooked for many reasons. For instance, it's the only bike the shop has in inventory, the salesperson gets a higher commission on certain bikes, etc. I believe the future of bike fitting will be to start with the right size (and right kind of) frame for the type

Continued on page 50

Continued from page 49

of riding the customer wants to do as well as match the frame dimensions to the customer's physical dimensions to maximize efficiency and comfort.

To be able to successfully fit a bike, "education is and will always be crucial," said Boon. "You can develop and sell the best tools in the world, but without education, they are of no added benefit for the consumer. Education needs to be aimed at teaching a process to the bike fitters, which helps them to develop their own standardized approach. One must also keep in mind that there needs to be a significant practical proportion in the training schedule, relative to the theoretical part. Finally, a certified dealer network is the key to success for any bike fitting system. I also see…physical therapists and bike industry professionals working together. Bike industry professionals are knowledgeable about bikes, but do not always have the best background in human physiology and anatomy, whereas physiotherapists are knowledgeable about the human body but not so much about the adjustment possibilities of a bicycle. So, I strongly believe we need both groups to have an interest in bike fitting and to cooperate with each other to bring the best possible service to cyclists. It is crucial to have a good process that is followed in a structured way…. This will bring the best possible results to our end consumers, ensuring that their cycling experience is optimized by the bike fitter."

Schultz said she is seeing an increase in PTs attending bike fitter courses compared to bike shop employees/bike shop owners. "I know the bicycle shops are extremely busy now, so I see the trend of the shops providing sales and service and 'farming out' the bike fitting piece to a trusted and highly qualified fitter, whether that is a PT or an independent fitter."

Bike Fitting Is a Big Tent

In my bike fitting education program, I am happy to see fitters with more diverse backgrounds, and I am seeing a greater percentage of students who are PTs. Along with personal trainers and bike shop employees and owners, this is the perfect mix of students, and everyone seems to learn a lot more in each class compared to if the class consisted of bike shop personnel only.

According to Stroot, today's good bike fitting education and technology will only get better and will find its way into the fitting industry so fitters will continue to improve their skills. He also sees a trend, brought on by COVID-19 lockdowns, where riders have more time to evaluate how they might improve. He was adamant that more riders should seek out bike fitters and that retailers need to take more of a key role in fitting.

For high-level athletes, a knowledgeable bike fitter is just 1 tooth in the cog. The others being a PT/physiotherapist, coach, trainer, and even a direct line to the saddle, shoe, and component manufacturers that know what changes to what equipment will result in changes to the cyclist's position on the bike. A regular cyclist might also need more insight to be able to ride more comfortably and injury free.

Brook said there are systems available that attempt to measure elements of the rider and adjust rider position automatically, and while they cannot replace a human fitter, that's the direction things are going. He said he understands the appeal of bike fitting machines from a shop's perspective: you buy the technology once, there's no ongoing salary, and the machine cannot leave and take the training with them. However, bike shops "need to be cautious because these systems aren't yet close to being able to offer the same level of service as a well-trained, professional bike fitter," he said, emphasizing the importance of the educational standards recently implemented by IBFI. "By improving both the quality and amount of training a fitter receives, the harder it will become for automation to replace the role."

Nevertheless, Brook acknowledged the initial appeal of new technology—that is, until the consumer realizes technology isn't capable of carrying out every aspect of a fit. "Until the tech moves on significantly, bike fitters aren't at serious risk of being replaced, but it's constantly improving so we have to improve the quality of the fitters and make it as hard as possible for technology to replace us," he said.

Education, Education, Education

One way to ensure that bike fitters remain relevant is to formalize and standardize education to raise standards around the world, said Brook. "The European Union has a very good approach to vocational training that the IBFI has mirrored in our recent education changes. We have created a common syllabus agreed upon by over a dozen education providers, with assessments for each module and external moderation. It's

Continued on page 52

Continued from page 51

a huge leap from where we were as an industry just 5 or 6 years ago, and I'm confident it's a system that will produce well-trained and well-rounded fitters."

As a level 4 fitter with IBFI, I agree with the direction the organization is taking to standardize and formalize the bike fitting process. For those new to bike fitting, there are classes (with continuing education credits) that can be taken to help with understanding bike fitting. After several hundred bike fits, the new bike fitter can test for level 1, after which they can then get a mentor assigned to them to help them understand more in-depth facets to bike fitting, the why's and how-to's.

I discussed what education a fitter needs with Stroot, and he mentioned 2 principal areas. First, as the categories of bikes increase (ie, cross bikes, gravel bikes, mountain bikes, road bikes, tri/time trial bikes, fit bikes like Peloton, Ebikes, etc.), bike fitting education will have to adapt to add specialties to fit those bikes. And second, fitters should understand strength, mobility, and nutrition.

Schultz said she is seeing a shift in gravel and mountain bikes gaining popularity over road bikes. And with this increase in popularity, she concurs with Stroot that fitters will need to brush up on skills that make sense fitting riders to these types of bikes. Asking her about body types, shapes, and dimensions, she said it still comes down to knowing how to measure angles—this part is still key and, yes, each person has unique dimensions that require custom measuring.

"The future of bike fitting is in the hands of the people that best understand the mechanisms and interplay between the adjustments that you could make," added Brook. "It's not about being a medical professional or not, it's about understanding the process. The IBFI's new common syllabus is based on the European Qualifications Framework (EQF), which creates parity between vocational and academic qualifications. It's the system commonly used by sports therapists in Europe, which is a similar role to an athletic trainer in the United States. So, it has a history of being used for complementary medical training, and level 4 carries the same weight as completing the first year of a bachelor's or undergraduate degree. Professionalizing education in this way bridges the gap between fitters and medical professionals, completely removing the argument that one would be better than the other."

The Value of Independence

Asking Schultz about bike fitting education, she believes independent fitters will be able to give better fits since they are not bound by any 1 bike company's philosophy, they are able to team with a physical therapist to treat clients when needed or assist different bike shops, and they are able to take continuing education that will help their quality of bike fitting like anatomy, physiology, kinesiology, etc., which will help them understand more about how the body moves and how it is supposed to move. She's talking more than a weekend course, she's talking about fitters becoming personal trainers, which will give them a lot of the above-listed education, as well as maybe enrolling in a community college for these courses.

> Fitters should understand strength, mobility, and nutrition

In general, she believes in fixing the body from imbalances rather than a band-aid approach, such as fixing muscle imbalances such as a tight abductor/weak adductor instead of placing wedges under the cleats to fix knee tracking.

Stroot summed it up by stating that "bike fitters have a lot of power to (a) keep a rider riding, and/or (b) help a racer maximize their potential."

I must agree with Schultz. Education is the future of bike fitting. Topics that bike fitters should take must include engineering, mechanics, physiology, and biomechanics. What we are really talking about is going back to the basics to be able to move forward.

Lastly, I spoke with Thomas who discussed where bike fitting needs to go in order to help the top professional athletes. "The future of bike fitting will be when bike fitters combine current fitting theory and fine tune it based upon individuals' physiology, including taking live metabolic measurements while fitting, such as oxygen consumption relative to watt production and aerodynamic modeling. This means fitters must not only have fitting equipment, but a metabolic cart with the capability to analyze gas

Continued on page 55

Continued from page 52

exchange, setting the person's actual bike on an ergo meter and photographic/computer modeling equipment to estimate drag coefficient. Specialized [Retul] has started this process, termed "metabolic fit," but it really needs to be combined with drag estimates. Furthermore, the type of racing you perform, ie, triathlon, TT, crit, road, must be taken into account since aerodynamics' importance decreases during racing that involves lots of climbing."

In summary,

A.) Education is still king!

B.) There needs to be continued work between the bicycle industry, kinesiologists, biomechanics, sports physiologists, and medical professionals. I have already seen a shift in attendees of my bike fitting educational classes, from bike shop employees/owners to almost exclusively PTs taking these courses. This makes sense since there would be no disruption in the continued care of an injured athlete in the process of rehabilitation.

C.) Bike sizing is the first step toward a successful bike fitting.

D.) For fitters using bike fitting machines, there needs to be an accurate way of taking the post-fit dimensions off of the fit bike and duplicating those dimensions exactly onto the client's actual bicycle. Take saddle height for example. There is an actual safe range for saddle height. Within that range, some cyclists feel stronger and more comfortable on the lower end of the scale, while others feel stronger and more comfortable on the higher end. This all has to do with leg length vs torso length and tibia length vs femur length. I might fit someone to where they feel the best, and if I raise the saddle 1mm, they will ask what I did, that feels terrible.

Note: Specialized Retul has such a system but something similar needs to be available for all bike fitting machines.

E.) Bike fitting in the future will integrate the processes from the customer starting off with the right-size bike and the right-size components to more pressure point and physiological analysis.

F.) Before automating bike fitting processes with tools and bike fitting machines, the fitter must know what the data is telling them and more importantly, know what to adjust on the bike based on this data.

G.) Bike fitting still relies on open and honest communication between the fitter and the client. The client's feedback during the fit about what feels right and what feels wrong is still the most important aspect. ler

Rick Schultz, MBA, DBA, is a master bike fitter (IBFI Level 4) and USA Cycling (USAC) Level 2 Coach and Certified Skills Instructor. He is the owner of Bike Fitness Coaching, San Juan Capistrano, California. Find him at BikeFitnessCoaching.com.

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New & Noteworthy

Noteworthy products, association news, and market updates

ÖSSUR POWER KNEE

Össur's POWERE KNEE is an actively powered microprocessor prosthetic knee for people with a transfemoral amputation or limb difference. The motor-powered "smart" prosthesis uses advanced algorithms to detect human movement patterns, thereby learning and adjusting to the wearer's speed and cadence in real-time. The POWER KNEE creates motion by providing active powered assistance while distinguishing whether the wearer is walking on varying surfaces, inclines, or declines, or sitting and standing. When ascending stairs, the wearer is able to perform a more natural step-over-step pattern, and experience more controlled resistance when descending stairs or ramps. The prosthesis' motor-powered energy helps encourage more symmetrical motion and enhance the wearer's endurance by helping them conserve their own energy.

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Digitsole has launched its second-generation Digitsole Pro® system and smart insoles. This system was developed with, and for, healthcare professionals to improve the clinical assessment of patients with mobility disorders. It represents an important assessment advancement that can help improve a patient's walking or running, and advance recovery from neurological, orthopedic, and age- or sport-related conditions by measuring objective biomechanical data that cannot be observed by the naked eye. Each Digitsole Pro® insole has an inertial platform that records the walking steps, running strides, and orientations of a foot in space. The connected chips inserted into a patient's insoles retrieve data collected at the end of each activity. Patient movements are processed through Digitsole Pro's proprietary artificial intelligence algorithm into relevant clinical data so practitioners can evaluate the quantitative and qualitative impact of movement and propose the most effective treatment options for patients.

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IDF DIABETES ATLAS 2021 AVAILABLE FOR DOWNLOAD

The International Diabetes Federation (IDF) Diabetes Atlas 10th edition is available for download. This publication provides detailed information on the estimated and projected prevalence of diabetes, globally, by region, country, and territory, for 2021, 2030, and 2045. It draws attention to the growing impact of diabetes across the world and highlights proven and effective actions that governments and policymakers must take to tackle it.

To download the publication, visit https://diabetesatlas.org/atlas/tenth-edition

NEW SUPER SOFT FOAM ROLLER

OPTP® has introduced the new PRO-ROLLER Super Soft Foam Roller to its product line. This foam roller features professional-quality and highly durable EVA foam construction, with a super soft density that offers the gentlest, most forgiving compression of all the PRO-ROLLER foam rollers. Ideal for people who are new to foam rolling, those with sensitive tissues, or those who require more stability, this foam roller can be used for gentle self-massage, physical therapy, stretching, Pilates and yoga exercise, and more. The PRO-ROLLER Super Soft is a standard size foam roller, measuring 36-inches in length and 6-inches diameter. It is easy to clean with a wet cloth and mild detergent or a sanitizing wipe.

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HYBRID ASSISTIVE LIMB (HAL) IMPROVES GAIT IN ALS PATIENTS

Amyotrophic lateral sclerosis (ALS) is a fatal progressive neurodegenerative disease that presents with various symptoms, such as muscle weakness, dysphagia, dysarthria, and respiratory failure, leading to death in 3–5 years. As ALS remains incurable, patient care including rehabilitation is important for maintaining the physical function and quality of life during the rapid progression of the disease.

The Hybrid Assistive Limb (HAL; CYBERDYNE Inc., Japan) is a cyborg-type wearable robot that supports gait training based on the wearer's intended motion. HAL is based on a technology called 'cybernics', in which the machine and human are connected and share information in real time, allowing the machine to support the voluntary movement of the wearer. HAL detects bioelectrical signals on the skin surface and provides support to the wearer's voluntary drive.

Professor Kano Osamu, MD, PhD, and his colleagues conducted a study to evaluate the effect of HAL-based training in ALS patients. Patients who were diagnosed with ALS at Toho University Omori Medical Center, Tokyo, between January and December 2019 and had an unsteady gait with the ability to walk for >10 m with assistance from caregivers and/or a walker were included. The gait training program consisted of 1 session per day (20–40 minutes per session), 2–3 days a week for at least 4 weeks. As a result, the distance of the 2-minute walk test (2MWT) improved, on average, from 73.87m to 89.94m after 1 course of training. Other outcome measures also showed some improvement or preservation.

"Our results show that cybernic therapy improves gait ability in ALS patients in a short period," said Kano. "This also suggests that continuous cybernic therapy may be able to suppress the progression of ALS and maintain [quality of life]."

ORTHOTICA LABS

Orthotica Labs, a state-of-the-art custom orthotics laboratory focused on lower extremity care, has officially launched following a successful 3-month beta testing program. With a focus on the practical needs of both doctor and patient, the lab's technology platform offers unparalleled functionality and ease of use while delivering custom-fabricated orthotics distin-

guished by quality, fit, and finish. The product portfolio was developed to streamline the ordering process yet provide a comprehensive set of options and personalizations. Orthotica Labs' custom foot orthotics are available across 4 product lines that address a broad range of functional control options; these include the company's Fit Line, Athletica Line, Ultra Line, and Contour Line. The company's ScriptWise® ordering system was developed to provide near single-click prescription writing for even the most challenging cases. The underlying technology is smart, efficient, and capable of generating any custom orthotic prescription in seconds.

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INTACT KNEE TEACHES PROSTHESIS TO ACT MORE REALISTICALLY

The intuitive process of walking is difficult to imitate in a natural, comfortable way for people who use robotic prostheses and exoskeletons. Toward this end, to better teach a prosthetic knee to act as naturally as possible, research collaboration based at Arizona State University (ASU) and North Carolina State University proposed a seemingly obvious instructor: the user's intact knee. But enabling a robotic prosthesis to work with a human

user is a complex problem that cannot be solved with classical control systems. Instead of mathematically describing the individual components and then controlling their actions, Jennie Si, a professor in the ASU School of Electrical, Computer and Energy Engineering said her team observed how the players worked together and then exerted control based on the new knowledge.

Si and her team developed a reinforcement learning algorithm with artificial intelligence to help the robotic knee copy the intact knee and tested it through computer simulations. They constrained the robotic knee's range to keep the partnered movements relatively stable but gave it the freedom to adjust based on the intact knee's actions. When walking on even ground at an even pace, the robotic knee mimicked the intact knee 100% of the time. When the terrain became uneven, the success rate dipped to 97%, with an average of just below 20 steps accurately taken. In the third scenario, where the walking pace increased and then slowed, the robotic knee could follow the intact knee with 80% accuracy but improved with more training.

"This is a dynamic problem, meaning the variables evolve over time," Si said. "The prosthetic can work in symmetry with the human to create a comfortable experience. The user doesn't need to stop and say, 'I am going up stairs now,' and wait for the robot to figure out how to do that. They can just go up the stairs together."

WORLD'S LARGEST COLLECTION OF GAIT ANALYSIS DATA OF HEALTHY INDIVIDUALS PUBLISHED

Biomechanical gait analysis can be a helpful tool when it comes to diagnosing gait problems and subsequently treating them. However, "until now there has been a worldwide lack of reference data for healthy persons," said Fabian Horst, PhD, of Johannes Gutenberg University Mainz (JGU), Germany. An adequate quantity of data on the walking characteristics of healthy individuals is needed to be able to reliably detect and classify pathological gait patterns and any causative ailments. Horst, a sports scientist, has now presented a database that will help to close this gap. The Gutenberg Gait Database is the world's largest publicly accessible database containing relevant information on healthy volunteers.

The database has been compiled by Horst and Djordje Slijepčević of St. Pölten University of Applied Sciences, Austria, and comprises data from 350 healthy volunteers, ages 11 to 64 years old, who attended the biomechanics lab at JGU over the past 7 years. The database contains ground reaction force (GRF) and center of pressure (COP) data measured for 2 consecutive steps, which were recorded by force plates embedded in the ground over the entire duration of ground contact of the feet. "Our data originated from 10 individual studies, so the (pre-)processing of the measured data had to be standardized before we could merge it," Horst added.

The Gutenberg Gait Database, which is now publicly accessible, provides users with both unprocessed raw data and processed ready-to-use data. According to Horst and Slijepčević , these data records offer new possibilities for future studies on human gait, eg, the application as a reference set for the analysis of pathological gait patterns, or for automatic classification using machine learning.

Another feature of the database is that it can be used in combination with GaitRec, the largest dataset of pathological gait patterns. "Combining these two data sources enables the development of more complex and robust algorithms for the automatic analysis of gait patterns," said Slijepčević .

The plan is to continually update the database, as well as to include more extensive and balanced data with regard to age and other factors.

To access the database, visit https://springernature.figshare.com/collections/Gutenberg_Gait_Database_A_ground_reaction_force_database_of_level_overground_walking_in_healthy_individuals/5311538/1.

PATELLA GEL PADS KNEE SLEEVES

Fuelmefoot's patella gel pads medical-grade knee sleeves are designed for meniscus tears, arthritis, ACL injuries and injury prevention, joint pain relief, and sports injury recovery. The sleeves, which are made using 3D-knitted moisture-wicking material, promote blood circulation in the knee. The thick acupressure patella pad enhances protection to the knee. The flexible, dual-side stabilizers offer stability and support allowing a full range of motion, while the ergonomic fit provides maximum comfort. The patella gel pads knee sleeves come in 5

sizes, based on thigh girth: S, 12.2–15.7"; M, 13.8–17.7"; L, 15.4–19.7"; XL, 16.5–21.7"; and XXL, 18.1–23.6".

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AOPA NATIONAL ASSEMBLY, SEPTEMBER 28 – OCTOBER 1

The 105th annual National Assembly of the American Orthotic & Prosthetic Association (AOPA) will be held September 28 – October 1, 2022, at the Henry B. Gonzalez Convention Center in San Antonio, TX.

New for 2022 is a 2-day education track on orthotic and prosthetic digital care, a 2-day education track on post-mastectomy care, an interactive event in the Exhibit Hall featuring patient success stories and their caregiver, and a fundraising event at Top Golf San Antonio. For additional information, visit www.aopanet.org/2022-aopa-national-assembly.

TEXTURED RECOVERY SOCKS

Naboso's new Recovery Socks combine the benefits of compression socks with targeted foot recovery with texture stimulation. The socks offer 3 primary benefits. First, they enhance circulation with a patent-pending texture specifically designed to penetrate the micro-vessels of the dermal layer in the foot, which improves circulation to the skin, nerves, muscles, and fascia. Second, they aid muscle recovery, working like a mini-massage by hundreds of tiny fingers across the bottom of the sock, releasing tension in the intrinsic muscles of the feet. Third, they increase neurostimulation by reconnecting the nerves in the bottom of the feet and creating a grounding and calming effect on the nervous system. The Naboso Recovery Socks, available in both ankle-high and knee-high lengths, come in sizes small through extra-large.

Naboso
347/705-0702
naboso.com

3D-PRINTED CUSTOM WALKING BOOTS

ActivArmor provides custom-fitted, waterproof, breathable, low-profile walking boots for fracture care and offloading using their free iPhone app digital scan. Create a precise 3D scan of the patient, marking any custom features (offsets/exposures), and ActivArmor will have a custom-designed boot in your hands in less than a week. The boots are 3D-printed from ISO10993-certified biocompatible plastic and adjustable for changes in edema, while lockable for compliance. Patients can bathe, shower, and swim while wearing the boot, and skin can be easily observed and treated while immobilized. These walking boots are covered by insurance, including Medicaid and Medicare, with over 50% durable medical equipment billing margins. Providers get their logo for free on every device, so patients market for them in their community.

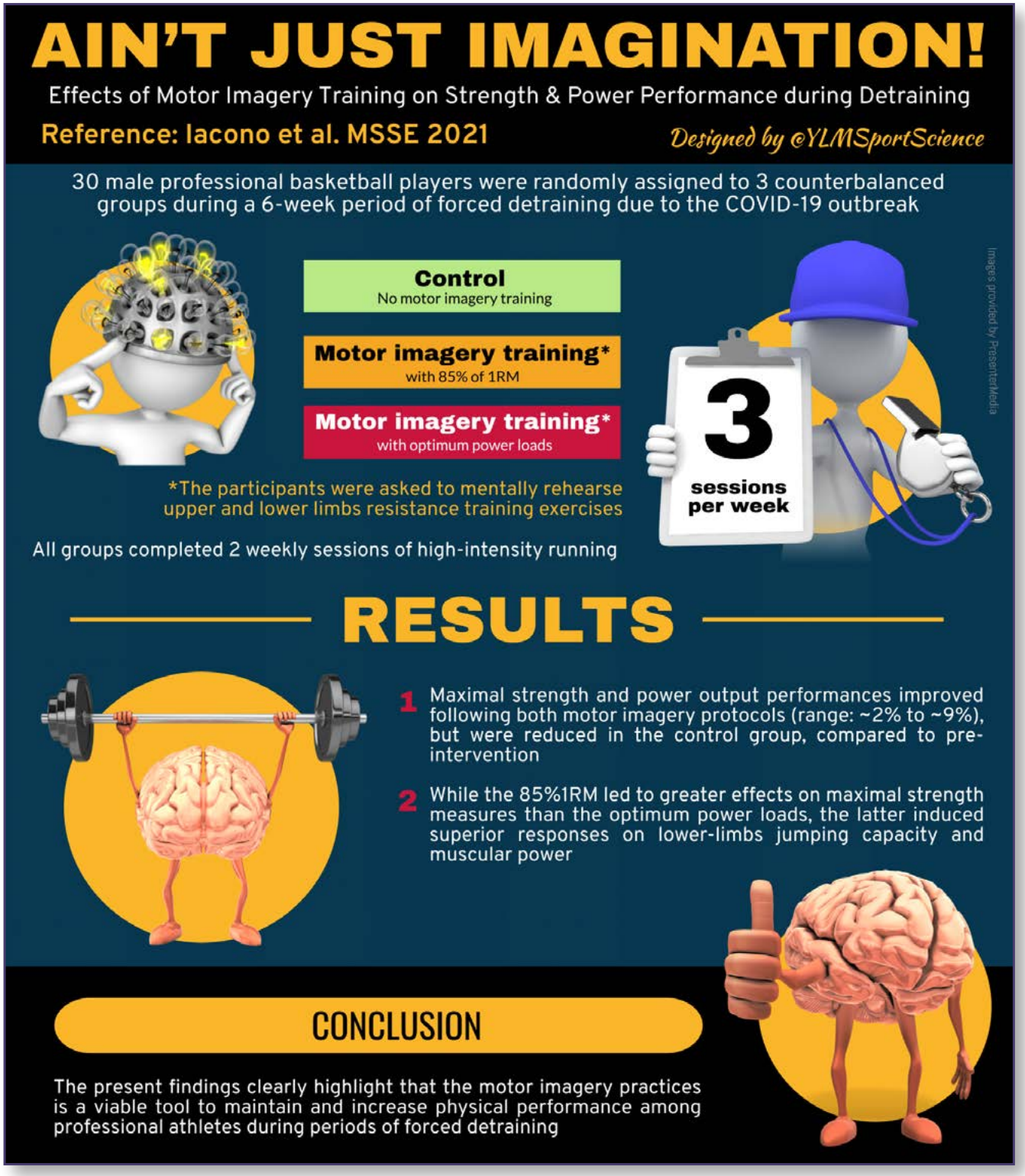
ActivArmor
800/583-6690
www.activarmor.com

MASTER OF SCIENCE IN O&P COMING TO SALUS UNIVERSITY

Salus University, Elkins Park, PA, will be launching a new master's program in Orthotics and Prosthetics (O&P), which will be housed within the College of Health Sciences, Education and Rehabilitation. The university is seeking accreditation by the National Commission on Orthotic and Prosthetic Education (NCOPE). It is anticipated that the inaugural class of students will start during the 2022–2023 academic year, pending a successful accreditation application.

Chad Duncan, PhD, CRC, CPO, has been appointed director of the program. He arrived on campus in September 2021 after serving as the director for the past 3 years of the prosthetics and orthotics program at Northwestern University, Chicago. Students in this program will learn in closely-knit cohorts alongside skilled faculty who are board-certified prosthetist-orthotists. New laboratory facilities are being constructed on the university's campus, providing state-of-the-art, dedicated training and learning spaces for students in O&P.

AIN'T JUST IMAGINATION! EFFECTS OF MOTOR IMAGERY TRAINING ON STRENGTH AND POWER PERFORMANCE OF ATHLETES DURING DETRAINING



Source: Dello Iacono A, Ashcroft K, Zubac D. Ain't Just Imagination! Effects of Motor Imagery Training on Strength and Power Performance of Athletes during Detraining. Med Sci Sports Exerc. 2021;53(11):2324-2332.

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