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LOWER EXTREMITY REVIEW

October 24 / volume 16 / number 10

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

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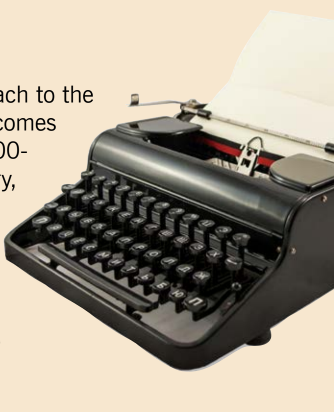

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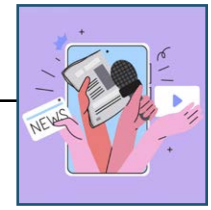
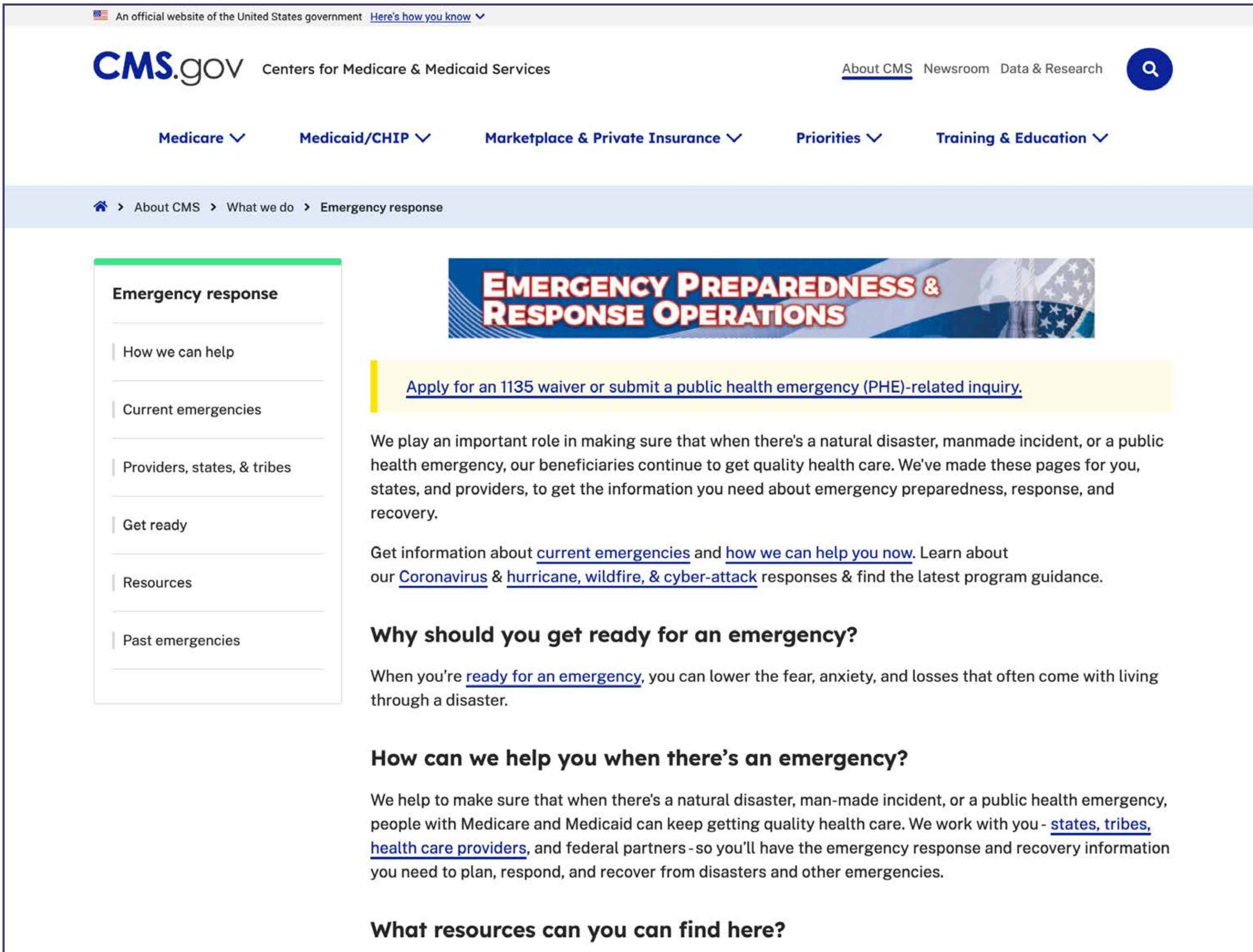
Please attach manuscript as an MS Word file or plain text. Tables may be included in the main document, but figures should be submitted as separate jpg attachments. Send to: **janice@lermagazine.com**

News You Can Use



CMS Announces Resources & Flexibilities to Assist in Hurricane Milton's Aftermath



The Centers for Medicare & Medicaid Services (CMS) announced additional resources and flexibilities available in response to Hurricane Milton in Florida. CMS is working closely with the State of Florida and federal partners to put these flexibilities in place to ensure those affected by this natural disaster have access to the care they need – when they need it most.

On October 7, 2024, President Biden determined that an emergency exists in Florida due to the emergency conditions resulting from Hurricane Milton beginning October 5, 2024, and continuing. Additionally, on October 8, 2024, Department of Health and Human Services (HHS) Secretary Xavier Becerra determined that a Public Health Emergency (PHE) exists in Florida and has existed since October 5, 2024.

CMS stands ready to assist with resources and waivers to ensure hospitals and other facilities can continue to operate and provide access to care to those impacted by the consequences of the hurricane.

The following is key information on resources for those affected and actions CMS is taking in response to the hurricane in Florida:

State of Florida Waivers

CMS waivers are available to providers in Florida who have been affected by Hurricane Milton. Healthcare providers who need additional flexibilities specific to the effects resulting from Hurricane Milton can submit a request to CMS here: **https://cmsqualitysupport.servicenowservices.com/cms_1135**

Marketplace Special Enrollment Period (SEP) for Hurricane Milton Victims

During a Federal Emergency Management Agency (FEMA) declared Major or Emergency disaster event, individuals who reside in states served by HealthCare.gov and who miss their existing SEP or who miss enrollment during the Open Enrollment Period are eligible for an SEP to enroll in Marketplace coverage. FEMA-emergency affected individuals will have up to 60 days from the end of the FEMA-designated incident period to select a new Marketplace plan or make changes to their existing Marketplace plan. FEMA-emergency affected individuals must contact the Marketplace Call Center at 1-800-318-2596 or TTY at 1855-889-4325 and indicate they were eligible for an enrollment window but were unable to complete their enrollment due to a FEMA-designated emergency or disaster. For more information, visit: **https://www.cms.gov/cciio/resources/regulations-and-guidance/fema_sep**

Disaster Toolkit and Support for State Medicaid and CHIP Agencies

To prepare for current and future disasters, CMS has developed an inventory of Medicaid and Children's Health Insurance Program (CHIP) flexibilities and authorities available to states in the event of a disaster to support Medicaid and CHIP operations and ensure continuity of coverage for people served through Medicaid and CHIP programs during times of crisis. For more information and to access the inventory and toolkit, visit **https://www.medicaid.gov/state-resource-center/disaster-response-toolkit/index.html**

Medical Equipment and Supplies Replacements

CMS will permit people with Medicare who have lost or realized damage to their durable medical equipment, prosthetics, orthotics, and supplies as a result of the hurricane to receive replacements of such items and services. This will help to ensure beneficiaries can continue to access the needed medical equipment and supplies they rely on each day. People with Medicare can contact 1-800-MEDICARE (1-800-633-4227) for assistance.

CMS will continue to work with the State of Florida and those areas impacted by the hurricane. We encourage beneficiaries and providers of healthcare services that have been impacted to seek help by visiting CMS' emergency webpage (www.cms.gov/emergency).

To find additional preparedness and response resources for the health sector and emergency management professionals, please visit: **https://www.phe.gov/emergency/Tools/Pages/default.aspx**

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The Editors of *Lower Extremity Review* want to highlight the work of thoughtful, innovative practitioners who have solved their patients' vexing problems. We are seeking reports of your most intriguing cases in the following areas:

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- Benefit of movement
- Prevention of diabetic foot ulcers
- Collaborative care

Before you begin to write, query the Editors about your proposed topic (email is fine). Doing so ensures that your manuscript will conform to the mission of the publication and that the topic does not duplicate an article already accepted for publication. Furthermore, a query often allows the Editors and the publication's advisors to make recommendations for improving the utility of the manuscript for readers.

Case reports should be no more than 1500 words (not including references, legends, and author biographies). Photos (≤4) are encouraged. Case reports can include a literature review as is appropriate for the topic. (Please note that for HIPPA compliance, photos should be de-identified before sending.)

Manuscripts must be original and not under consideration for publication elsewhere. Any prior publication of material must be explained in a cover letter.

All authors must be medical professionals in good standing. Students will be considered as first author only when the byline includes a fully licensed professional.

Manuscripts are submitted with the understanding that they will be reviewed; that revisions of content might be requested; and that the editorial staff will undertake editing, as necessary, aimed at improving clarity and conciseness and applying conformity to style.

Authors will have the opportunity to review and approve the edited version of their work before publication.

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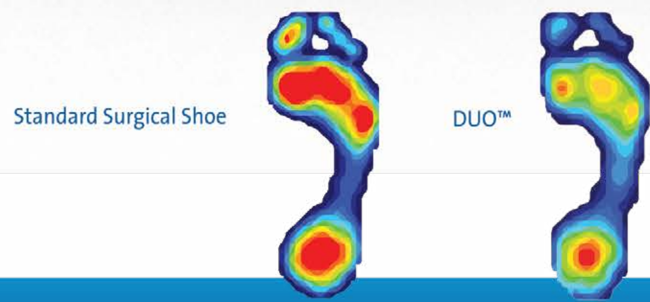

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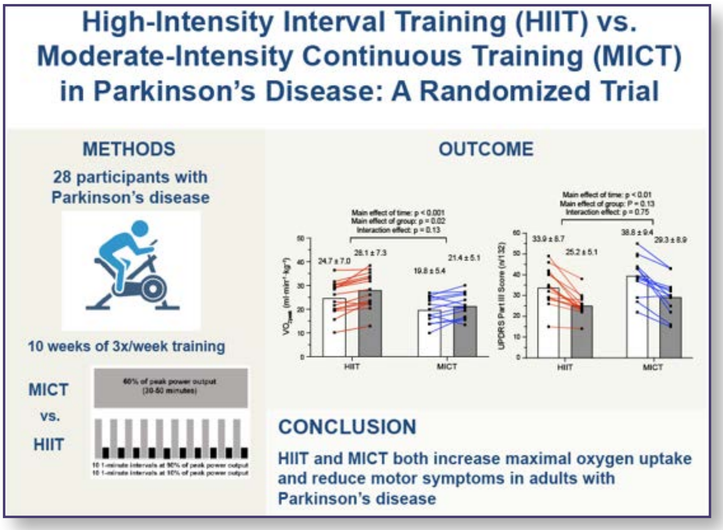
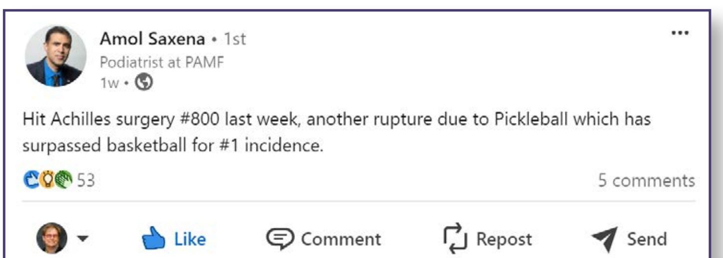


Source: *Kathia MM, Duplea SG, Bommarito JC, et al. High-intensity interval versus moderate-intensity continuous cycling training in Parkinson's disease: a randomized trial. J Appl Physiol (1985). 2024;137(3):603-615. doi: 10.1152/japplphysiol.00219.2024. © 2024 the American Physiological Society; all rights reserved.*

LinkedIN Post of Note: Pickleball Strikes Again!



Date Posted: Sept. 21, 2024

Texture Changes in Heel Pad Macrochambers May Foretell Soft Tissue Damage in Diabetes

Diabetic foot ulcers pose a serious threat to people with diabetes, especially the elderly. Both aging and diabetes can lead to structural and compositional changes in the plantar soft tissues which can be seen on ultrasound. With an increasingly aged population and diabetes prevalence expected to increase to nearly 25% among adults age 75-79, this older population is at greater risk for foot ulcers. Indeed, the lifetime incidence rate of foot ulcers is up to 34% among those with diabetes. All this combines to make an elderly population at high risk for diabetic foot ulcers (DFUs). Given that the heel is a known high-risk site for DFUs, it is worthy of research attention.

This study aims to use the texture analysis of ultrasound images to distinguish the features of microchambers (a superficial thinner layer) and macrochambers (a deep thicker layer) in heel pads between the elderly with and without Type 2 diabetes, so as to preliminarily explore whether texture analysis can identify the potential injury characteristics of deep tissue under the influence of diabetes before the obvious injury signs can be detected in clinical management.

Ultrasound images were obtained from the right heel (dominant leg) of 11 elderly people with diabetes (DM group) and 11 elderly people without diabetes (Non-DM group); mean age in both groups was 85 years. The Tek-Scan system was used to measure the peak plantar pressure (PPP) of each participant. Six gray-level co-occurrence matrix (GLCM) features including contrast, correlation, dissimilarity, energy, entropy, and homogeneity were used to quantify texture changes in microchambers and macrochambers of heel pads.

The researchers found significant differences in GLCM features (correlation, energy and entropy) of macrochambers between the 2 groups, while no significant differences in all GLCM features of microchambers were found between the 2 groups. No significant differences in PPP and tissue thickness in the heel region were observed between the 2 groups.

In the elderly with diabetes who showed no significant differences in PPP and plantar tissue thickness compared to those without diabetes, several texture features of ultrasound images were found to be significantly different. This finding, the authors concluded, indicates that texture features (correlation, energy and entropy) of macrochambers could be used for

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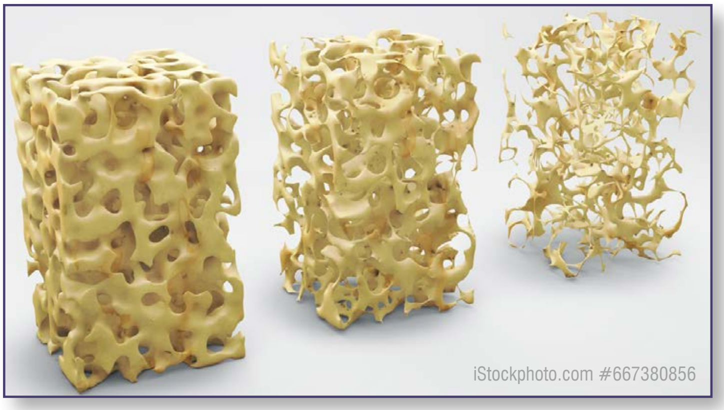
early detection of soft tissue damage associated with diabetes.

Source: *Duan Y, Ren W, Xu Y, et al. Texture differences of microchambers and macrochambers in heel pads between the elderly with and without diabetes. J Tissue Viability. 2024:S0965-206X(24)00122-0. doi: 10.1016/j.jtv.2024.07.016.* *© 2024 Tissue Viability Society / Society of Tissue Viability; all rights reserved.*

Goal-Directed Osteoporosis Treatment: ASBMR/NHOF Task Force Position Statement 2024



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The overarching goal of osteoporosis management is to prevent fractures. A goal-directed approach to long-term management of fracture risk helps ensure that the most appropriate initial treatment and treatment sequence is selected for individual patients. Goal-directed treatment decisions require assessment of clinical fracture history, vertebral fracture identification (using vertebral imaging as appropriate), measurement of bone mineral density (BMD), and consideration of other major clinical risk factors. Treatment targets should be tailored to each patient's individual risk profile and based on the specific indication for beginning treatment, including recency, site, number and severity of prior fractures, and BMD levels at the total hip, femoral neck, and lumbar spine. Instead of first-line bisphosphonate treatment for all patients, selection of initial treatment should focus on reducing fracture risk rapidly for patients at very high and imminent risk, such as in those with recent fractures. Initial treatment selection should also consider the probability that a BMD treatment target can be attained within a reasonable period of time and the differential magnitude of fracture risk reduction and BMD impact with osteoanabolic versus antiresorptive therapy. This position statement of the ASBMR/BHOF Task Force on Goal-Directed Osteoporosis Treatment provides an overall summary of the major clinical recommendations about treatment targets and strategies to achieve those targets based on the best evidence available, derived primarily from studies in older postmenopausal women of European ancestry.

Source: *Cosman F, Lewiecki EM, Eastell R, et al. Goal-directed osteoporosis treatment: ASBMR/BHOF task force position statement 2024. J Bone Miner Res. 2024;39(10):1393-1405. doi: 10.1093/jbmr/zjae119.*

NATA Study Highlights Overuse Injuries in High School Sports

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Participation in high school sports has physical, physiological, and social development benefits, but it also increases the risk of acute and overuse injuries. Risk of sport-related overuse injury differs between boys and girls. These authors sought to investigate differences in overuse injuries among high school athletes participating in the gender-comparable sports of boys' and girls' basketball and soccer and boys' baseball and girls' softball.

The nationally representative data from the 2006–2007 to 2018–2019 academic years comes from High School Reporting Information Online (RIO), the National High School Sports-Related Injury Surveillance Study. The authors extrapolated national estimates and rates of overuse injuries from weighted observed numbers with the following independent variables: sport, gender, academic year, class year, event type, body site, diagnosis, recurrence, activity, and position.

Key among their findings:

- Girls were more likely to sustain an overuse injury than boys (soccer, injury rate ratio [IRR]: 1.37, 95% CI = 1.20–1.57; basketball, IRR: 1.82, 95% CI = 1.56–2.14; baseball/softball, IRR: 1.21, 95% CI = 1.04–1.41).
- Findings from this study can help guide future strategies that are more specific to gender and sport to reduce overuse injuries among high school athletes.

Other findings include: Among an estimated 908,295 overuse injuries nationally, 43.9% (n = 398 419) occurred in boys' soccer, basketball, and baseball, whereas 56.1% (n = 509,876) occurred in girls' soccer, basketball, and softball. Most overuse injuries in soccer and basketball for both genders occurred to a lower extremity (soccer: 83.9% [175,369/209,071] for boys, 90.0% [243,879/271,092] for girls; basketball: 77.0% [59,239/76,884] for boys, 80.5% [81,826/101,709] for girls), whereas most overuse injuries in baseball and softball were to an upper

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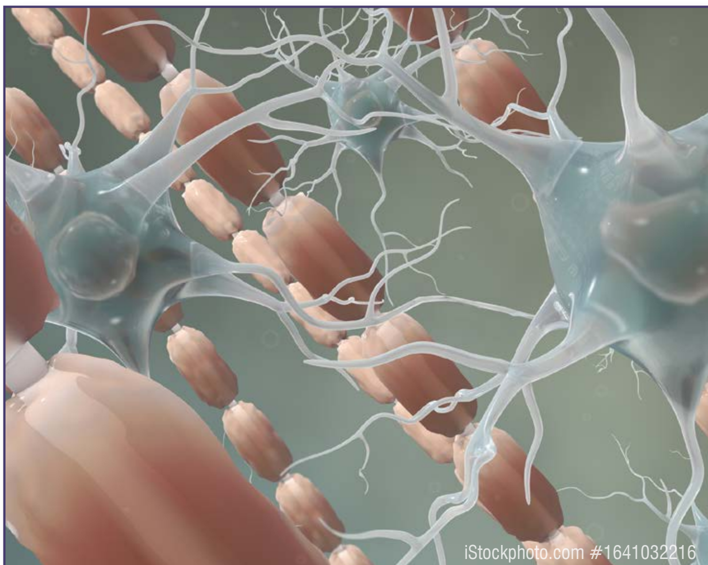
extremity (72.5% [81,363/112,213] for boys, 53.7% [73,557/136,990] for girls). For boys' baseball, pitching (43.5% [47,007/107,984]) was the most common activity associated with an overuse injury, which differed from the most common activity of throwing (31.7% [39,921/126,104]) for girls' softball.

***Source:** Bunstine JL, Yang J, Kistamgari S, Collins CL, Smith GA. Differences in Overuse Injuries in Gender-Comparable Sports: A Nationally Representative Sample of High School Athletes.J Athl Train. 2024; 59 (9): 962–968. doi: https://doi.org/10.4085/1062-6050-0040.23*

Some MS Therapies May Not Slow Disability Progression



In people with primary progressive multiple sclerosis (MS), a new study has found no difference in the amount of time before disability worsened between people taking certain medications and those not receiving treatment. The study was published in a recent issue of the journal *Neurology*®, the medical journal of the American Academy of Neurology.

With MS, the body's immune system attacks myelin, the fatty, white substance that insulates and protects the nerves. People with primary progressive MS experience a steady decline in symptoms. About 10% to 15% of people with the disease have this type of MS. The study looked at rituximab and ocrelizumab, anti-CD20 infusion therapies that target a protein called CD20 found on some white blood cells called B-cells. Removing these cells from the bloodstream is believed to reduce inflammation and damage that can occur to the myelin. Ocrelizumab is approved by the U.S. Food and Drug Administration (FDA) for primary progressive MS and for people with relapses, but rituximab is not. Rituximab is FDA approved for other diseases like rheumatoid arthritis and prescribed off label for MS.

"MS is a disabling disease, so treatments that slow the progression to worse disability are sorely needed," said study author Laure Michel, MD, PhD, of Rennes University in France. "Anti-CD20 therapies are widely prescribed, in part because there are few alternate treatments. However, our study suggests they may not slow disability from worsening for people with primary progressive MS."

The study involved 1,184 people with primary progressive MS who had an average age of 56. They did not take MS medications in the 2 years prior to the study. For the study, 295 people were treated with rituximab, 131 were treated with ocrelizumab and 728 were untreated. They were followed for an average of 4 years.

Participants' level of disability was measured on a scale with scores ranging from zero, meaning no symptoms, to 10 points, meaning death due to MS. At the start of the study, all participants had a score of 6.5 or less.

Researchers then measured how long it took for people to advance to their first confirmed disability progression. For those whose score was less than 5.5 at the start of the study, advancing one point on the scale was considered progressing in disability. If their score was 5.5 or more, advancing 0.5 points on the scale was disability progression. After adjusting for possible differences between the treated and untreated groups, researchers found there was no difference in the time it took to progress to the next level of disability between those taking a medication and those taking no medication.

"Medications for MS can be expensive and come with risks of side effects," said Michel. "Our results indicate that there should be a constant evaluation of MS therapies to determine if the benefits outweigh the risks for people with primary progressive MS."

A limitation of the study is that it was a look back in time and did not follow people in real time. Also, among those taking medications, most were taking rituximab with fewer people taking ocrelizumab. More research is needed in larger groups of people to confirm the findings.

***Source:** Hay M, Rollot F, Casey R, et al; as the OFSEP Investigators. Anti-CD20 Therapies in Drug-Naive Patients With Primary Progressive Multiple Sclerosis: A Multicenter Real-Life Study. Neurology. 2024;103(8):e209886. doi: 10.1212/WNL.0000000000209886.*

Pediatric Hurdling Injuries

Hurdling is a unique track event due to a combination of running and jumping over an apparatus. Since hurdling requires a special skillset with sprinting and jumping, athletes are at risk for various musculoskeletal injuries. These authors noted a paucity of studies describing the epidemiology of pediatric hurdle injuries and sought to examine hurdle-related injury types, injured body parts, injury mechanisms, and injury settings in children and adolescents.

This was a descriptive epidemiology study using data from the National Electronic Injury Surveillance System (which represents emergency room visit) which was retrospectively reviewed. Injury data involving hurdle injuries was searched during a 10-year period (2008-

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2017) with hurdlers 18 years old and younger. Injuries were classified based on injury types, body parts, injury mechanisms, and injury settings. Descriptive statistics were used including mean ± standard deviation, frequency (N), and percentages (%).

A total of 749 hurdle-related injuries were found from 333 males (44.5%) and 416 females (55.5%). The top 3 injury types were fracture (N = 218, 29.1%), joint sprain (N = 191, 25.5%), and contusion/hematoma/bruise (N = 78, 10.4%). The top 3 injured body parts were ankle (N = 140,18.7%), knee (N = 120, 16.0%), and wrist (N = 69, 9.2%). The most common injury mechanisms were apparatus-related trips, falls, and landings (N = 594, 79.0%). Finally, injury settings consisted of track and field practices (N = 469, 62.6%), track and field meets (N = 96, 12.8%), and other settings including gym, physical education class, recess, school activities, and camps (N = 49, 6.5%).

The authors concluded that in pediatric hurdle athletes, the most prevalent injury type seen in the emergency room was fracture. Although most hurdle-related injuries occur in the lower extremity, wrist injuries were the third most commonly injured body location. The most common injury mechanism was apparatus-related trip, fall, and landing, and injuries most commonly occurred during track practices. In pediatric hurdle athletes seen in the emergency room, the majority of injuries consisted of traumatic fractures and joint sprains at ankle, knee, and wrist, which frequently occurred with apparatus-related trip, fall, and landing mechanisms during track and field practices. ler

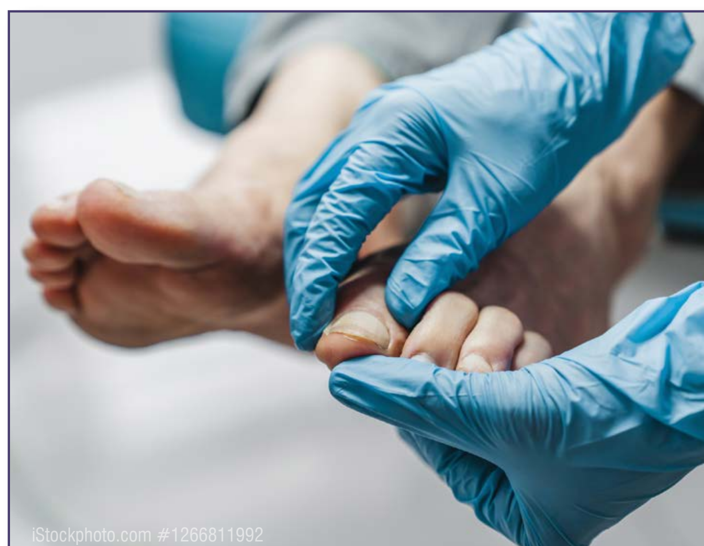
Source: *Radel LC, Jones JC, Garcia K, Soma DB, Miller SM, Sugimoto D. Pediatric hurdle-related acute injuries in track and field presenting to US emergency departments: descriptive epidemiology study. Phys Sportsmed. 2023;51(4):379-386. doi: 10.1080/00913847.2022.2120371.*

Long-Term Follow-Up Assesses Efficacy of Fosravuconazole for Onychomycosis in Elderly

Onychomycosis is a chronic and intractable disease whose prevalence increases during aging. In elderly patients, if onychomycosis is left untreated and progresses to a severe stage, it may cause functional decline of the lower limbs due to foot pain. This could lead to a decline in activities of daily living and secondary impairment such as cognitive decline. Thus, the treatment of onychomycosis in elderly patients is important.

These authors, from Hokkaido, Japan, have previously shown that fosravuconazole is relatively safe and effective for onychomycosis in elderly patients. Fosravuconazole was approved in Japan in 2018 for the treatment of fungal nail infections; it is not currently approved by the US Food and Drug Administration for use in the United States.

This study continued follow-up and investigated the efficacy of re-administration of fosravuconazole in patients with recurrent onychomycosis. One hundred and twenty-five patients age ≥65 years who had been initially diagnosed with onychomycosis at their hospital's dermatology department, and who had responded well to fosravuconazole at 48 weeks after the initial treatment, were followed up until 144 weeks after the start of the initial treatment. Patients who experienced a recurrence within 24 weeks after the start of the follow-up were assigned to the short-term recurrence group, and those who experienced a recurrence after 24 weeks were assigned to the long-term recurrence group. All patients in both groups were re-treated with fosravuconazole to evaluate its efficacy.



The short-term and long-term recurrence groups consisted of 17 (14.3%) and 10 (8.4%) patients, respectively. The researchers found no significant differences in mean age and sex ratio between the 2 groups. There were no serious adverse effects in either group, and the toenail opacity ratio was significantly reduced after 12 weeks of re-treatment in both groups. The short-term and long-term recurrence groups were

Continued on page 21

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significantly more likely to have wedge-shaped onychomycosis and total dystrophic onychomycosis, respectively. The results suggest that re-administration of fosravuconazole is safe and as effective as the first administration for elderly patients with recurrent onychomycosis.

Source: *Okubo A, Hanada M, Kodama S, Taniguchi N, Miyazaki Y. Long-term follow-up study of the efficacy of fosravuconazole in the treatment of onychomycosis in elderly patients. J Dermatol. 2024;51(8):1091-1097. doi: 10.1111/1346-8138.17254.* *© 2024 Japanese Dermatological Association; all rights reserved.*

Broström-Gould Procedure: 5-Year Follow-Up

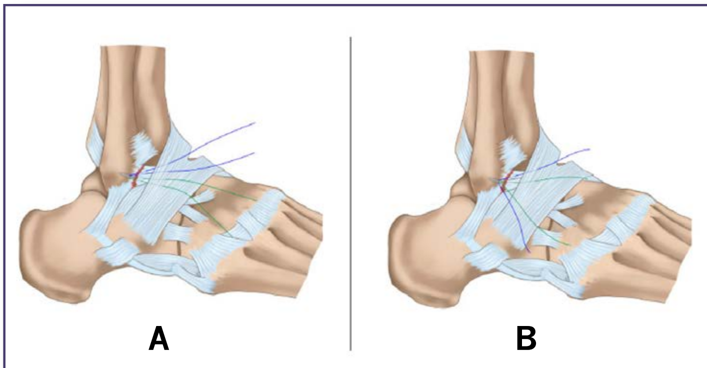

Figure. A) Surgical diagram of arthroscopic Broström–Gould procedure with horizontal mattress suture fashion. B) Surgical diagram of arthroscopic Broström–Gould procedure with free-edge suture fashion. Reprinted from Feng SM, Han M, Wang AG, Fan JQ. Functional Comparison of Horizontal Mattress Suture Versus Free-Edge Suture in the All-Inside Arthroscopic Broström-Gould Procedure for Chronic Lateral Ankle Instability. Orthop Surg. 2020;12(6):1799-1810. doi: 10.1111/os.12817. Use is per Creative Commons Attribution License.

Ankle sprains are a common musculoskeletal injury among the general population and often involve the lateral ligament complex. Although the majority of ankle sprains are treated successfully with nonsurgical conservative measures, an estimated 5% to 20% of ankle injuries ultimately develop chronic lateral ankle instability (CAI). Multiple surgical treatment modalities for the lateral ankle complex exist, such as anatomical and non-anatomical reconstruction. The current gold standard for primary surgical repair is the Broström-Gould (BG) procedure. This is the first article to provide PROMIS scores following BG and the largest study with 5-year outcomes for an open BG. (PROMIS, Patient-Reported Outcomes Measurement Information System.)

This was a descriptive study of a retrospective cohort of patients undergoing a BG with a minimum follow-up of 5 years. Patient-reported outcome instruments collected postoperatively were PROMIS Pain, Physical Function, Depression, and Foot and Ankle Ability Measure (FAAM). Further preoperative clinic characteristics were analyzed to correlate with the final outcome. The electronic medical record was queried for Current Procedural Terminology (CPT) code 27698 (Broström-Gould) from January 2010 to June 2017. Surveys were conducted in the clinic and through phone interviews. Patient charts were reviewed to obtain basic patient demographic information including sex, age, race, and body mass index (BMI). The following preoperative variables were recorded: history of prior CAI procedures, history of major trauma, duration of symptoms, number of diagnosed ankle sprains, other collagen pathologies, generalized ligament laxity, participation in sports/activity level, peroneal subluxation, clinically diagnosed peroneus longus or brevis tendinopathy, deltoid ligament injury, anterior ankle impingement, and posterior ankle impingement. The PROMIS and FAAM scores were obtained with a combination of clinic and phone interviews. Data were aggregated in Microsoft Excel and entered in R (version 4.2.0) for statistical analysis.

Table. Individual Regression Analysis for Each Outcome Measure.

	T Value	*P* Value
FAAM sports		
Peroneal tenodesis	−2.3	.02
FAAM ADL		
Tobacco use	−2.3	.02
Peroneus longus tendinopathy	−2.4	.02
Peroneus brevis tendinopathy	1.7	.1
PROMIS PF		
Age >50 y	−2	.05
PROMIS PI		
Tobacco use	2.43	.02
Diabetes	−2.03	.047
Participate in sports activities	−2.8	.01
Peroneus longus tendinopathy	0.52	.6
MRI report peroneal pathology	−1.23	.23
Calcaneal osteotomy	−1.62	.11
PROMIS depression		
Age >50 y	−2.9	.01
History of major trauma	−2.1	.04
Varus stress test	3.2	<.001
Tobacco use	3.8	<.001

Abbreviations: ADL, activities of daily living; FAAM, Foot and Ankle Ability Measure; PF, physical function; PI, pain interference; PROMIS, patient reported outcome measurement information systems survey.

Results show that the minimum 5-year patient-reported PROMIS scores for patients following a Broström-Gould procedure are as follows: PROMIS physical function, 50.5; PROMIS pain interference, 48.2; and PROMIS depression, 38.2. This indicates, at a minimum, that patients 5 years removed from the procedure are within 1 standard deviation (SD) of the general population in regard to PROMIS physical function and pain. The patient-reported FAAM, activities of daily living, and FAAM sports scores were 59.6 and 13.0, respectively. Linear regression to understand the factors significantly impacting patient reported outcomes are seen in the Table. The following variables were statistically significant: FAAM score peroneal tenodesis, FAAM ADL tobacco use, PROMIS

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PF age > 50, PROMIS PI tobacco use, diabetes, participate in sports activities, PROMIS depression age > 50, history of major trauma, varus stress test, and tobacco use.

Preoperative magnetic resonance imaging (MRI) findings were recorded. Arthroscopic examination was performed before lateral ligaments reconstruction for patients with intra-articular pathologies confirmed on MRI.

These findings offer evidence supporting the effectiveness of the Broström-Gould procedure to be associated with normal physical function, even 5 years after surgery. Furthermore, this research identified specific factors such as tobacco use, diabetes, and sports participation that independently correlated with reported outcome measures. These insights enable physicians to better manage patient expectations and tailor treatment strategies accordingly. This study establishes a foundation for future prospective research endeavors that aim to leverage the PROMIS system for comprehensive outcome assessments.

***Source:** Scheinberg M, Sanchez T, Sankey T, et al. Patient-Reported Outcomes Following Open Broström-Gould Procedure: Minimum 5-Year Follow-Up. Foot Ankle Orthop. 2024;9(1):24730114241228272. doi: 10.1177/24730114241228272. Use if per CC BY 4.0.*

Reducing Prosthetic Stiffness Can Improve Running in Females with Leg Amputations

Similar to nonamputees, female athletes with unilateral transtibial amputation (TTA) using running-specific leg prostheses (RSPs) may have worse running economy and higher rates of running-related injury than male athletes. These authors hypothesized that optimizing RSP configuration for female athletes could improve running economy and minimize biomechanical asymmetry, which has been associated with running-related injury.

Nine females with a TTA ran at 2.5 m/s while we measured metabolic rates and ground reaction forces. The runners used an RSP with a manufacturer-recommended stiffness category, 1 category less stiff and 2 categories less stiff than recommended.

Use of an RSP 2 categories less stiff resulted in 3.0% lower net metabolic power (P = 0.04), 7.8% lower affected leg stiffness ($P = 6.01 \times 10^{-4}$), increased contact time asymmetry (P = 0.04), and decreased stance average vertical ground reaction force asymmetry (P = 0.04) compared with a recommended stiffness category RSP.

Lower RSP stiffness (kN/m) values were associated with lower net metabolic power (P = 0.02), lower affected leg stiffness ($P = 1.36 \times 10^{-4}$), longer affected leg contact time ($P = 1.46 \times 10^{-4}$), and similar affected leg peak and stance-average vertical ground reaction force compared with higher RSP stiffness values.

The runners then used the RSP stiffness category that elicited the lowest net metabolic power with 100 g, 200 g, and 300 g added distally. No significant effects of added mass on net metabolic power, biomechanics, or asymmetry were found.

The authors concluded that females with unilateral transtibial amputation can improve running performance through reductions in net metabolic power by using an RSP that is less stiff than manufacturer-recommended. Lower RSP stiffness values are associated with greater leg stiffness and contact time asymmetry, and lower stance-average vertical ground reaction force asymmetry.

***Source:** Ashcraft KR, Grabowski AM. Effects of prosthetic stiffness and added mass on metabolic power and asymmetry in female runners with a leg amputation. J Appl Physiol (1985). 2024;137(1):85-98. doi: 10.1152/japplphysiol.00522.2023.* *© 2024 the American Physiological Society; all rights reserved.*

Lateral Ankle Ligament Repair Lets Older Adults Remain Active

Researchers from Emory University School of Medicine recently reported that the annual incidence of lateral ankle ligament repair (LALR) has

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been on the rise since 2009, particularly among those over 70 years of age. They queried the IBM Watson Health Market Scan Database for patients who underwent LALR from January 2009 to December 2019 based on CPT code 27698. Volume and incidence per 100,000 population were determined for annual sums, gender, age, and geographical regions based on population estimates from the United States Census Bureau. Future annual volumes were statistically projected with linear regression modeling to the year 2032.

Overall, they identified 160,457 LALR procedures in the database from 2009 to 2019. Annual incidence increased 76.6% from 3.46 to 6.11 cases per 100,000 population, while estimates of annual volumes are projected to increase 61.5% from 19,829 to 32,033 procedures in the year 2032.

Interestingly, the researchers noted that the greatest increase in incidence was observed among patients above 70 years old, which might suggest older patients are staying active longer and desiring elective procedures to maintain their active levels. They concluded by noting that as the incidence of LALR increases in older patients, more research will be needed to understand the unique surgical considerations and risk factors impacting patient-reported outcomes.

Source: *Ellis LN, Karzon AL, Bariteau JT, Labib SA, Kadakia RJ, Coleman MM. Lateral Ankle Ligament Repair Is Not Only for Young Patients: Trends in Incidence and Demographics. Foot Ankle Spec. 2024:19386400241266361. doi: 10.1177/19386400241266361. Used with permission.*

Curcumin Alleviates Osteoarthritis Through the P38MAPK Pathway

A recent report in the *Journal of Inflammation Research* found that curcumin modulates chondrocyte oxidative stress, inhibits OA inflammation, and inhibits phosphorylation of the p38/MAPK pathway; the model used Sprague-Dawley rats. It also inhibits chondrocyte apoptosis and matrix degradation while promoting cartilage repair through multiple pathways and targets, as validated by network pharmacology, molecular docking techniques, and experimental studies. The authors, from various institutions in China, noted that the clinical application of curcumin is limited by its low bioavailability, primarily due to poor solubility, stability, and biobarrier permeability, and encouraged future studies that focus on improving the drug's properties, including such strategies as nanotechnology, liposome encapsulation, or combination with other drugs that could enhance its bioavailability.

Source: *Wang X, Yu H, Zhang Y, et al. Curcumin Alleviates Osteoarthritis Through the p38MAPK Pathway: Network Pharmacological Prediction and Experimental Confirmation. J Inflamm Res. 2024;17:5039-5056. doi: 10.2147/JIR.S459867.*

2MTIR vs PR for Achilles Tendon Rupture

Acute closed midsubstance Achilles tendon rupture (ACMATR) is common, with various treatment methods developed over time. These authors retrospectively compared the 2 mini transverse-incision repair (2MTIR) with percutaneous repair (PR) to determine which method yields better results. (See Figures 1 and 2.)

All cases meeting criteria from 2018 to 2021 in the University of Hong Kong-Shenzhen Hospital were included and followed up for 1 to 5 years. A final questionnaire with multiple indexes was conducted via phone call. Comparative analysis of these indexes between the 2 groups was performed using IBM SPSS Statistics (V.26). Continuous variables that passed tests for normality and equal variance were compared using the Student's t-test. Ranked data were compared using the Mann-Whitney U test. Categorical variables were tested with the chi-square test or Fisher's exact test. A P-value of less than 0.05 was considered statistically significant.

Their results showed 1 re-rupture in the PR group. The final indexes for "Tightness Feeling", "Heel Rising Strength", and "Foot Numbness" were statistically different ($P < 0.05$) between the 2 groups. The "Re-rupture" and "Return to Sports" indexes showed no statistical difference ($P > 0.05$).

The authors concluded that the 2MTIR technique provided a technically straightforward, minimally invasive procedure with well preserved paratenon and direct end-to-end firm fixation in cases of ACMATR. It resulted in very low complications, easy rehabilitation, and full weight-bearing as early as 5–6 weeks postoperatively, yielding better functional outcomes compared to the PR technique in the 1–5 year follow-up.

Source: *Jin WT, Huang LF, Guo HH, Wang L, Li X, Wang ZJ. Two mini transverse-incision repair yields better results than percutaneous repair for acute closed midsubstance Achilles tendon rupture: a retrospective case-control study. J Orthop Surg Res. 2024;19(1):452. doi: 10.1186/s13018-024-04904-8. Use is per Creative Commons Attribution 4.0 International License.*

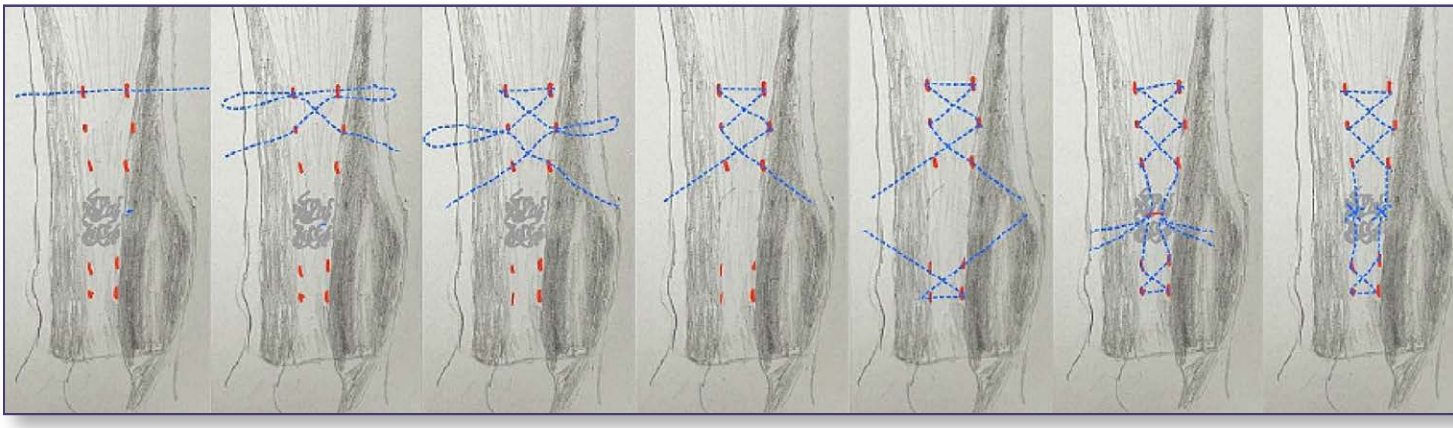

Figure 1: Surgical procedure step by step. Keys Red Dash — Stab Wound, Blue Dots Line - Suture, Blue Cross -- Knots

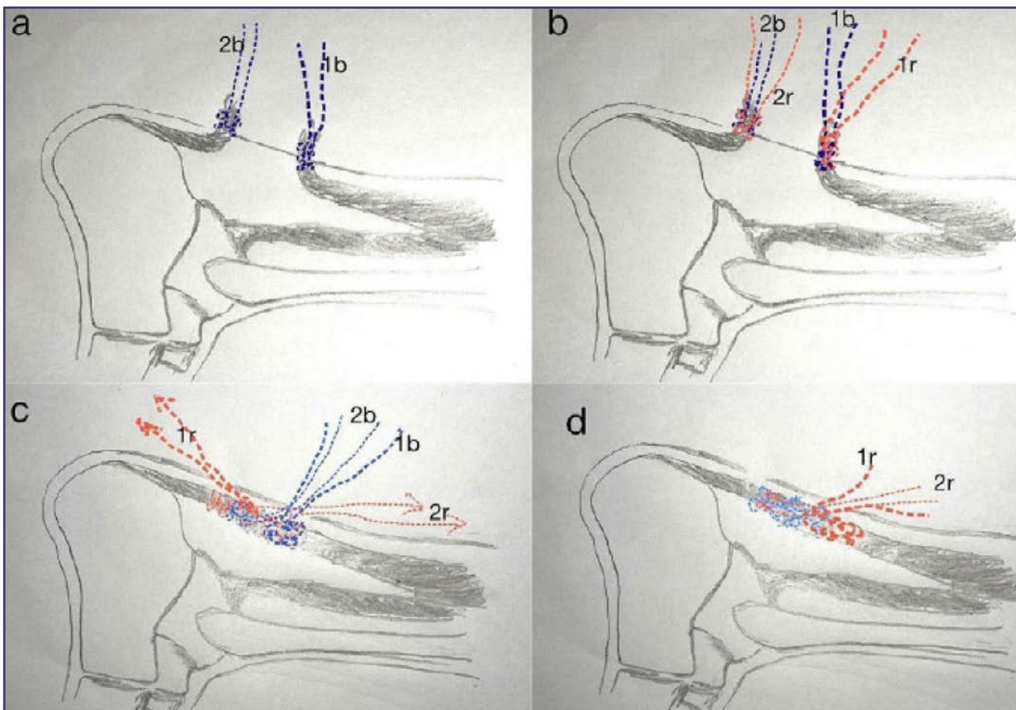

Figure 2: The 2MTIR technique. **(a)** Two stumps were exposed through separate transverse mini incisions. One suture (1b and 2b) was placed in a Krackow pattern in each of the stumps. **(b)** A second, different color suture (1r and 2r) was placed in each of the stumps. **(c)** Sutures 1r and 2r were threaded through the tunnel to the opposite incision to pull the two stumps together, and the 2b suture ends were threaded through the tunnel to the proximal incision and tied in knots with 1b. **(d)** The 1r ends were threaded to the proximal incision and tied in knots with 2r

Minimalist School Shoes Improve Intrinsic Foot Muscle Size, Strength, Arch Integrity

Minimalist walking shoes have been shown to improve foot muscle size and strength in active adults, but not in previous studies involving children, which could relate to the more structured footwear used in this study. Hence, this study examined the effects of true minimalists on intrinsic foot muscle size and strength, foot arch integrity, and physical function among primary school children.

After a baseline assessment, 30 primary school students aged between 9 and 12 were given a pair of minimalist shoes (Softstar Youth Primal RunAmoc [Softstar Shoes, Oregon, USA] with minimalist index = 92%) as their regular school shoes for 2 school terms, followed by a re-assessment.

Seventeen of the 30 participants in the minimalist group completed the study. Compared to the control group, the minimalist group showed

- significantly increased cross-sectional area of abductor hallucis (*P* = 0.047, Cohen's d = 0.57) and flexor digitorum brevis (*P* = 0.037, Cohen's d = 0.80),
- increased strength of the hallux (*P* = 0.015, Cohen's d = 0.76) and lesser toes (*P* = 0.014, Cohen's d = 0.66),
- greater arch height (*P* = 0.020, Cohen's d = 0.52) and standing long jump distance (*P* = 0.001, Cohen's d = 9.79).
- The control group exhibited improved standing long jump performance only (*P* = 0.020, Cohen's d = 10.70).

The authors concluded that minimalist shoes worn daily to school

Continued on page 26

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The Softstar Youth Primal RunAmoc. Image provided by Softstar Shoes.

promote intrinsic foot muscle size and strength, and improve foot arch integrity among primary school students.

Source: *Fong Yan A, Quinlan S, Cheung RTH. Minimalist school shoes improve intrinsic foot muscle size, strength, and arch integrity among primary school students. J Sports Sci. 2024;42(12):1157-1163. doi: 10.1080/02640414.2024.2386213.*

Does Occupation Footwear Influence Slip Response?

This study investigated how walking in occupational footwear (OF) affects slip outcome and slip recovery strategies in response to an unexpected slip. Participants walked along a walkway while either barefoot (BF; n = 13) or in OF (n = 12). The first five walking trials consisted of the no-slip condition, where a high friction sheet was placed halfway down the walkway to ensure a low probability of a slip. Prior to the sixth walking trial and without the participant's knowledge, the sheet was replaced with a low friction surface to induce an unexpected slip. Results obtained during the no-slip trials indicated that compared to the BF group, the OF group walked with a 15% smaller required coefficient of friction (P = 0.04), a 12° greater dorsiflexion at heel strike (P = 0.007) and a 7° more extended knee position at 100 ms following heel strike (P = 0.008). The OF group also demonstrated greater electromyographic (EMG) activity in the hamstrings of the stance limb and the gastrocnemius of the contralateral limb prior to and after heel strike. When the low friction surface was unexpectedly encountered, a slip was induced in both groups. But compared to the BF group, the OF group experienced a less severe slip, with the slip being 42% shorter (P = 0.004) and 75% slower (P < 0.001), and exhibited a 19–71% lesser EMG activation when responding to the slip. Although these results provide initial evidence for the benefits of wearing OF to minimize the consequence of a slip in the workplace, further research is needed to determine whether the altered walking patterns associated with wearing OF (eg, greater dorsiflexion, reduced knee range of motion, etc.) may have contributed to the decrease in slip severity.

Source: *Yuan VF, Tokuno CD. The influence of occupational footwear on slip responses. Footwear Science. 2024;16(3):219–229. https://doi.org/10.1080/19424280.2024.2363530.* *© 2024 Taylor & Francis Group; all rights reserved.*

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CLINICAL PERSPECTIVE

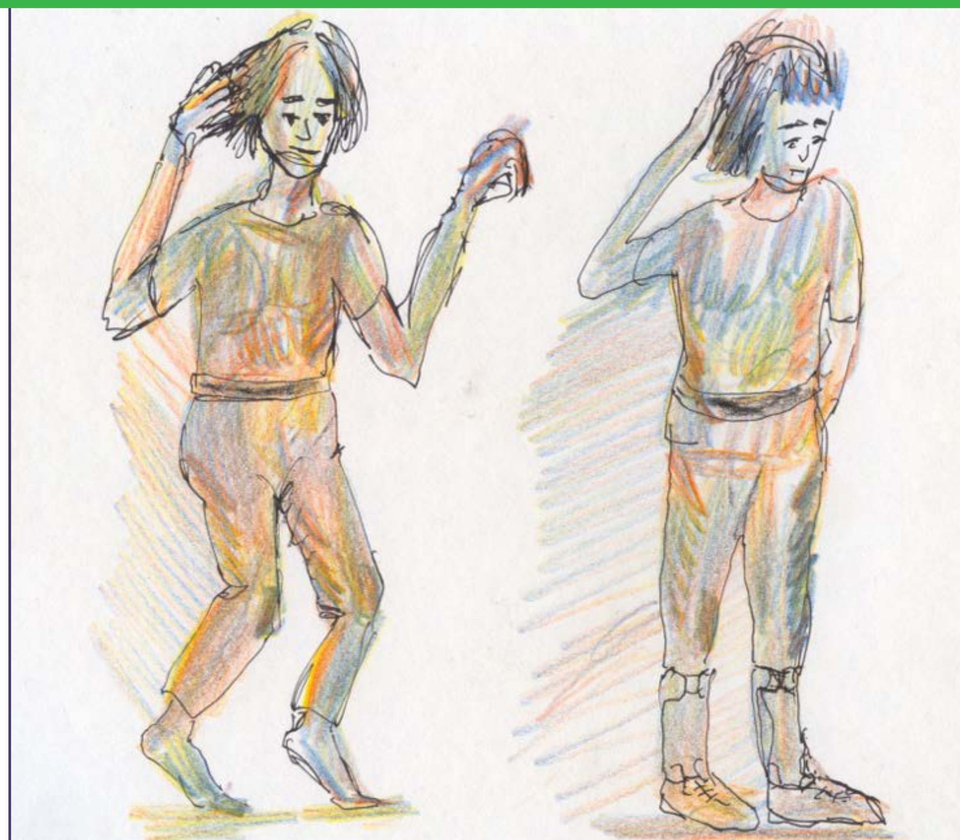
Posture and Autism: Sitting. Standing, and Toe-Walking Behavior

By Dalia Zwick PT, PhD

The other day, Anka (not her real name), a 19-year-old woman with Autism Spectrum Disorder (ASD) came to our clinic for her regular follow-up visit. While she walked independently, she exhibited severe Toe-Walking Behavior (TWB). She was accompanied by her father and an older brother. Her father was holding a bag with her Posterior Leaf Splint (PLS), a type of ankle-foot orthosis (AFO). When we asked how she is doing, her father said that she is doing very well. He then placed the AFOs and her sneakers on her feet and lower legs, and viola, now she was placing her heel down in standing, sitting, and walking positions—no more TWB.

My clinical role as a physical therapist is to assess needs and provide proper care for individuals with Physical or/and Intellectual Disabilities (PD/ID), including those who have ASD. I work at a clinic we call PT, P&O (short for Physical Therapy, Prosthetics & Orthotics), meaning that during every visit a physical therapist and a certified orthotist are present. Both of us contribute our professional knowledge and although, at times, we might have different opinions, we discuss and develop the best approach that both of us with our different perspectives as well as the individual and their circle of care agree on.

We've been following Anka's posture and gait challenges at our clinic, every 6 months for the last 7 years. Our approach to her posture and gait issues is to observe her standing, sitting, and walking with and without shoes and to assess her ankle range of motion (ROM). We then compare current assessments to the previous visits and adjust the angle of plantar flexion in the AFO accordingly. We review home physical therapy (PT) instructions with the family, which includes drawings of exercises, and reminders of posture care, which means alignment in every posture and support under the heel even when sitting and wearing the AFO while awake. The PLS AFO type of brace is customized to support and prevent her from plantar flexion tendency with a lift, as a support under the heel. Every 6 months we alter, repair, and reduce the amount of the heel lift as her plantar flexor contractures elongate (Figure 1). Anka received PT at her school, but it was inconsistent and eventually halted as the PTs were unable to justify the therapy within the educational system. Common, yet unfortunate reality.



Images of Anka. Left, Anka toe walking without Posterior Leaf Splint Solid Ankle-Foot-Orthoses. Right, note downward heel placement while using Posterior Leaf Splint Solid Ankle-Foot-Orthoses. *Original images provided by author.*

So why has today's visit left us with feelings of failure and disappointment? Are we doing everything we can to help Anka with her posture and gait issues? Before answering these questions let's review the general understanding of the underlying issues of posture and Autism.

Posture and Autism

Postural and gait impairments, including toe walking, are extremely prevalent among individuals with Intellectual Disability and those who have ASD or are on the spectrum. Why this occurs in this population is not fully known.

What we do know is that the tendency to hold a particular body position in an abnormal way causes stress on the joints, muscles and vertebrae column. It appears that many individuals with ASD have a limited repertoire of movement combined with sensory processing issues and therefore they are less likely to change from an unnatural position into a better posture.

Continued on page 30

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Continued from page 28

Change in posture occurs when the body gives a sensory signal of discomfort. It is obvious that long duration of staying in an abnormal posture may cause body distortions, soft tissue changes, weakness, and pain. Eventually this may lead to a reduction in ability or motivation to participate in functional daily activities.

Some of the postural impairments that are often observed are kyphosis, scoliosis, leg length discrepancy, distortions of foot and ankle joints, and various gait deviations. Many of these postural impairments are manifestations of the disorder: they result from the individual staying in or holding unnatural positions which force muscles, tendons, and ligaments to be under biomechanical stresses which increase pressure on joints, bones, and spinal discs. These positions may happen while lying, sitting, standing, and/or walking (Figure 2). Research in this area is extremely limited and it is mostly from anecdotal reports from patient chatboards or websites such as Quora.

Here's a comment from an individual with ASD describing his awkward sitting posture on an internet chatboard[1]—note the drive for comfort in one's own body:

"I don't know why I prefer to sit that way...I wish I could break the habit; I think it's bad for my lower back. But when I have my feet on the floor, I feel uncomfortable, and I have to keep shifting around a lot."

Here's what other patients have told us:

- "TWB is it's an urge it's a need it's a need to tighten"
- "Many individuals with ASD have an urge to tighten we have tight shoulders some of us we some of us don't move our arms when we walk"
- "Lack of grounding or a kind of flowing in a river floating along and there's no ground there's no support, no stability no firm foothold grounding"
- "A sign of fear it's a sign of anxiety and a defense against that fear and a defense against that anxiety"
- "It might have something to do with retained primitive reflexes some of these reflexes we might have it as infants"

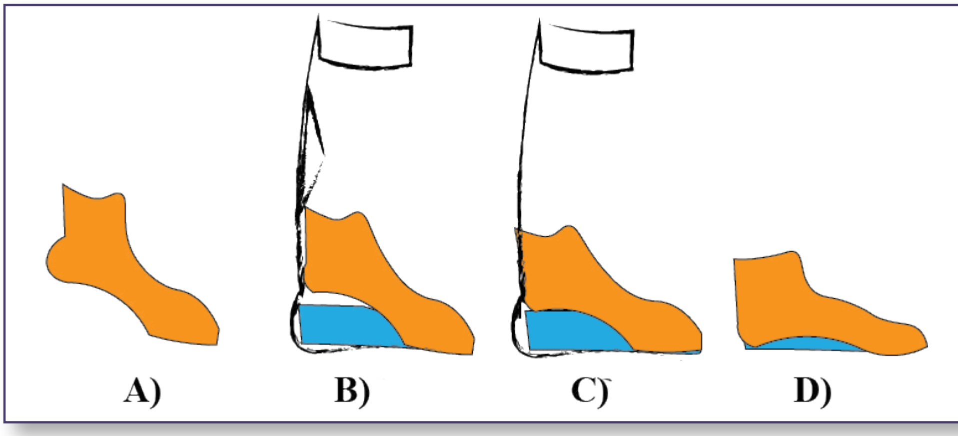

Figure 1. Sketch depicting the process of fitting the brace with a lift and gradually reducing the need for the heel lift or the brace; custom orthotics continue to support the ankle/foot complex. A) Toe walking without a brace. B) Heel is still up, but brace with a lift is added. C) Heel is slowly and volitionally lowered reaching the brace. D) Heel is down, and a lifelong custom orthotic is provided to help support the ankle/foot complex.

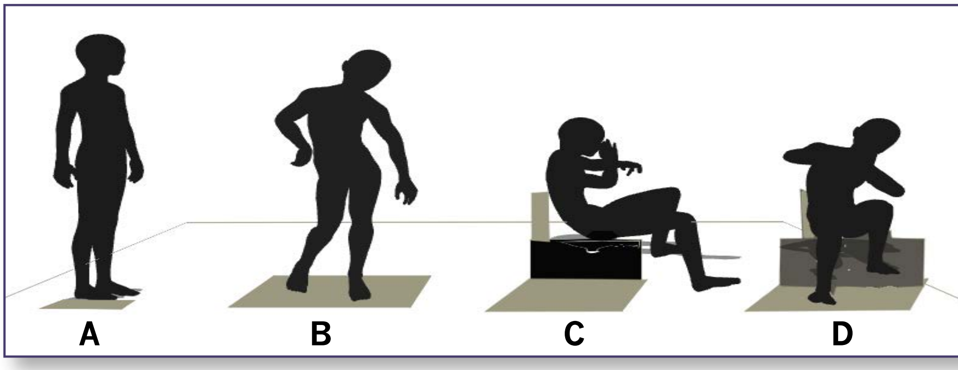

Figure 2. A) good standing position; B), C), and D) represent unnatural positions, which, when held too long, can become habitual and changes the shape of the body.

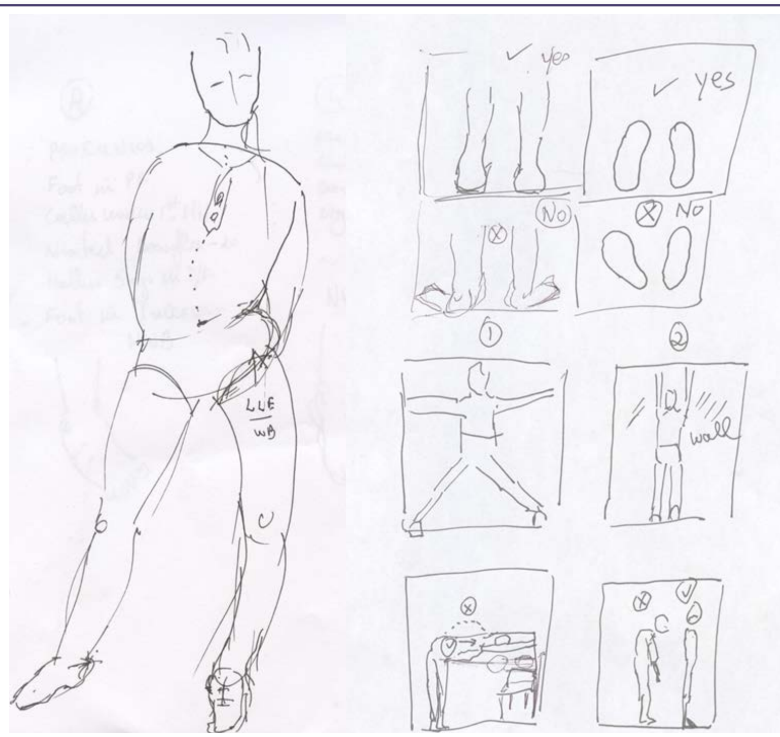

Figure 3. Office sketches with annotations.

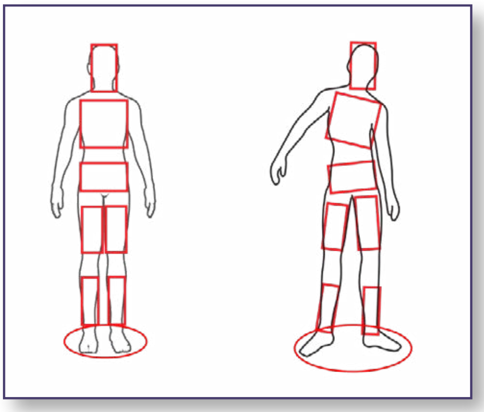

Figure 4. When viewing the body as stack of boxes, it is easier to see the difference between proper posture (left) and misaligned or abnormal posture (right).

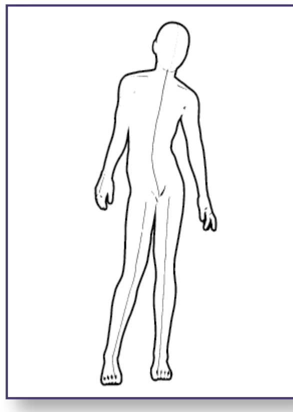

Figure 5. Note Contrapposto posture with left leg carrying most of the weight.

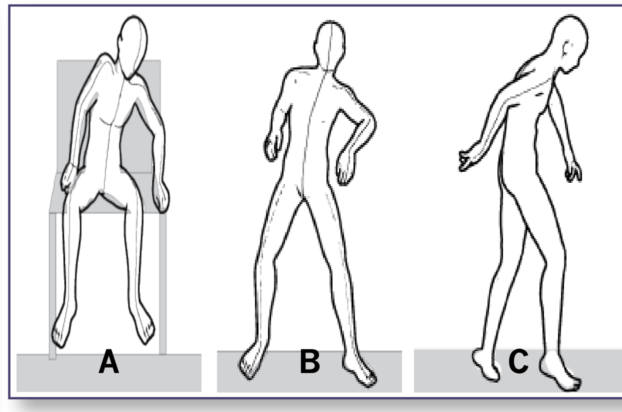

Figure 6. NA) sitting in abduction with external rotation and feet hanging in plantar flexion; this positioning is often translated into B) standing and C) walking; note the position of the knee and subtalar joint in the side view C).

- One girl's father told us: "Look at boxers before a fight." So I googled and found this: It's a gesture that people make when they are excited or impatient. They are standing on the ground while they use their toes to bounce up and down.

Assessing Posture in Clinic

PT assessment includes observation of an individuals' posture when they are sitting, standing, and walking barefoot both without and with shoe wear. On certain occasions, lying posture assessment is also needed. I often sketch people on the bus, or subway or while in urban gathering areas. As a therapist, I realized that sketching movement and posture of patients helps me pay attention to important details. I often draw a very rudimentary basic contour outline or even stick figure of an individual's posture and annotate what I observe (Figure 3). This process helps me explain and share with patients/caregivers.

I try to observe as an artist would. Artists study the shape, angles, and curves of the human body to accurately depict it. The level of attention that is required to do so improves one's overall observational skill as well as understanding of the human body.

When observing posture, it helps imagining proper posture of the body as a stack of symmetrical, aligned shapes with midline or line of gravity, viewing it from different directions and different positions. When viewing posture, one should try to imagine how the line of gravity passes through the body. Ask yourself the question: Is what you see a set of stacked shapes that is well aligned? Or is it misaligned boxes? (Figure 4.)

Standing Posture

When standing, we all often tend to stay in an asymmetrical posture, shifting weight onto one leg—habitually it will be the same preferred leg. When we do so, we often get a sensation of discomfort, and unconsciously shift to the other leg. It appears that individuals with ASD ignore this discomfort sensation and stay consistently on the same single leg. At times, the bodily discomfort of continuing to stand in this posture, instead of shifting the weight to the other leg, may trigger behavioral issues, such as nervousness or impatience (often described as fidgeting), or fatigue. Standing on the same single leg may have long-term effects of hip migration or limb length discrepancy, and, at a later stage, may cause a reduction in or loss of the ability to walk.[2]

In art, models are purposely asked to shift weight onto a single leg in standing, so the body will appear asymmetrical with pronounced curvatures. The term used to describe the artistic posture is Contrapposto. Contrapposto standing is characterized by placing most of the body weight on one leg (Figure 5). The leg that carries the weight of the body is known as the engaged leg and it is straight, hyperextended, or at times slightly bent, while the free leg without the weight is often rotated and bent. This posture is often seen in individuals with ASD. However, because of the extended length of time individuals stay in this contrapposto position, it may cause pain, and it often acts as a short leg.

Key questions to ask when assessing standing posture include: *Is weight evenly distributed on feet, and if not, what leg is bearing most weight? What and where are compensations taking place at the other leg's knee, foot, and ankle?* If you can answer these questions, you will begin to understand the main issue in an individual's posture.

Sitting Posture

Postural impairments of adults with ASD can be best explained as the consequence of early life poor habits untreated, or undermined and unresolved issues. In sitting, we often see abduction and external rotation of the legs which will affect standing. This abduction and external rotation may start as a habit and eventually will be observed in standing and walking (Figure 6). Placement of feet will affect the rest of the body, causing distortion to different body parts, eg, the externally abducted leg will enhance pronation at the subtalar joint.

Toe-Walking Behavior

Toe walking is most frequent in children with ASD, followed by individuals with communication disorders and learning disabilities.[3] A 2019 study by Leyden et al reported that 8.4% of patients with ASD had a diagnosis of toe walking compared with typically developing children where only 0.47% had a diagnosis of persistent toe walking.[4]

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Figure 7. These images show outcome of uncorrected toe walking in adulthood (2 different individuals in different age groups). Pronation of subtalar joint, abduction of midtarsal joint and hallux abductis valgus. Without proper bracing, damage will continue to allow soft tissues to shorten, which will lead to improper alignment making the condition into a deformed and permanent condition. This is why lifelong therapy is necessary.

Toe walking is a bilateral gait abnormality in which a normal heel strike/contact is absent and most weight bearing throughout stance phase of gait is on the forefoot.[5] It is often observed in standing as well as during sitting. Toe walking by itself is described as Idiopathic Toe Walking (ITW, without a known reason).[6] Here we focus on toe standing and walking behavior (also referred to as Toe-Walking Behavior or TWB), a better term which describes this phenomenon as extending beyond just walking.

In ASD, restricted and repetitive behaviors (RRBs) are defined as a series of behaviors and activities or interests that manifest regularly and interfere with daily functioning.[6] Studies have shown that there is a clear relationship between RRBs and emotional states among individuals with ASD, as RRBs have been linked to anxiety and stress.

Although toe walking is not described specifically as such in the original *The Repetitive Behavior Scale for Early Childhood* (RBS-EC),[7] it is described as such in the Diagnostic and Statistical Manual of Mental Disorders – 5 TR™ under the item Repetitive Motor definition: consecutive, non-social movements or actions that are repeated in a similar manner. And it is measured as:

0 – behavior does not occur
1 – behavior occurs about weekly or less
2 – behavior occurs several times a week
3 – behavior occurs about daily
4 – behavior occurs many times a day

What Happens During TWB?

Toe-walking behavior is most often or eventually accompanied by shortening of the calf muscle and other lower extremity soft tissues which further increases toe walking and the habitual standing habit. During initial gait phase, the lack of use of ankle dorsiflexion ROM leads to lack of heel contact (or as some describe it, strike), which further contributes to TWB.[8] Research shows that there is a relationship between persistent toe walking and the development of ankle limitation in ROM into dorsiflexion which is needed in standing and walking. Persistent TWB in individuals with ASD is related to the shortening of the Achilles Tendon (AT), which leads to a decrease of ankle ROM in dorsiflexion.[9] However, it is not clearly understood why some individuals with ASD develop a decrease of ankle ROM in dorsiflexion while others do not.

Calf muscles, especially the gastrocnemius muscle, which is a 2-joint or biarticular muscle, have a role to elongate during the stance phase of gait. Passive insufficiency occurs when an antagonist muscle, in this case the gastrocnemius, is unable to relax and elongate.[10] The foot/ankle complex may compensate in various ways for the limited ability to stand and walk with heel touching the ground. As a child matures and gains weight, this limitation may cause pain, discomfort, and even calluses. In adults, it is exhibited by distortions of the foot and ankle complex due to weight, lack of passive elongation flexibility, or weakness (Figure 7). The result is a foot and ankle that are prone to pain, injury, and distortion. This may explain resistive unusual behavior or refusal to continue walking after a short distance.

Most families and some therapists are not aware that individuals who have TWB need to be followed throughout the life span. Insurance companies most often will cover an annual evaluation and will allow for custom orthotics where the condition warrants it so proper support will be provided for the foot/ankle. This support will prevent deformity and instability and allow for continuous proper and safe ambulation. For a

Continued on page 35

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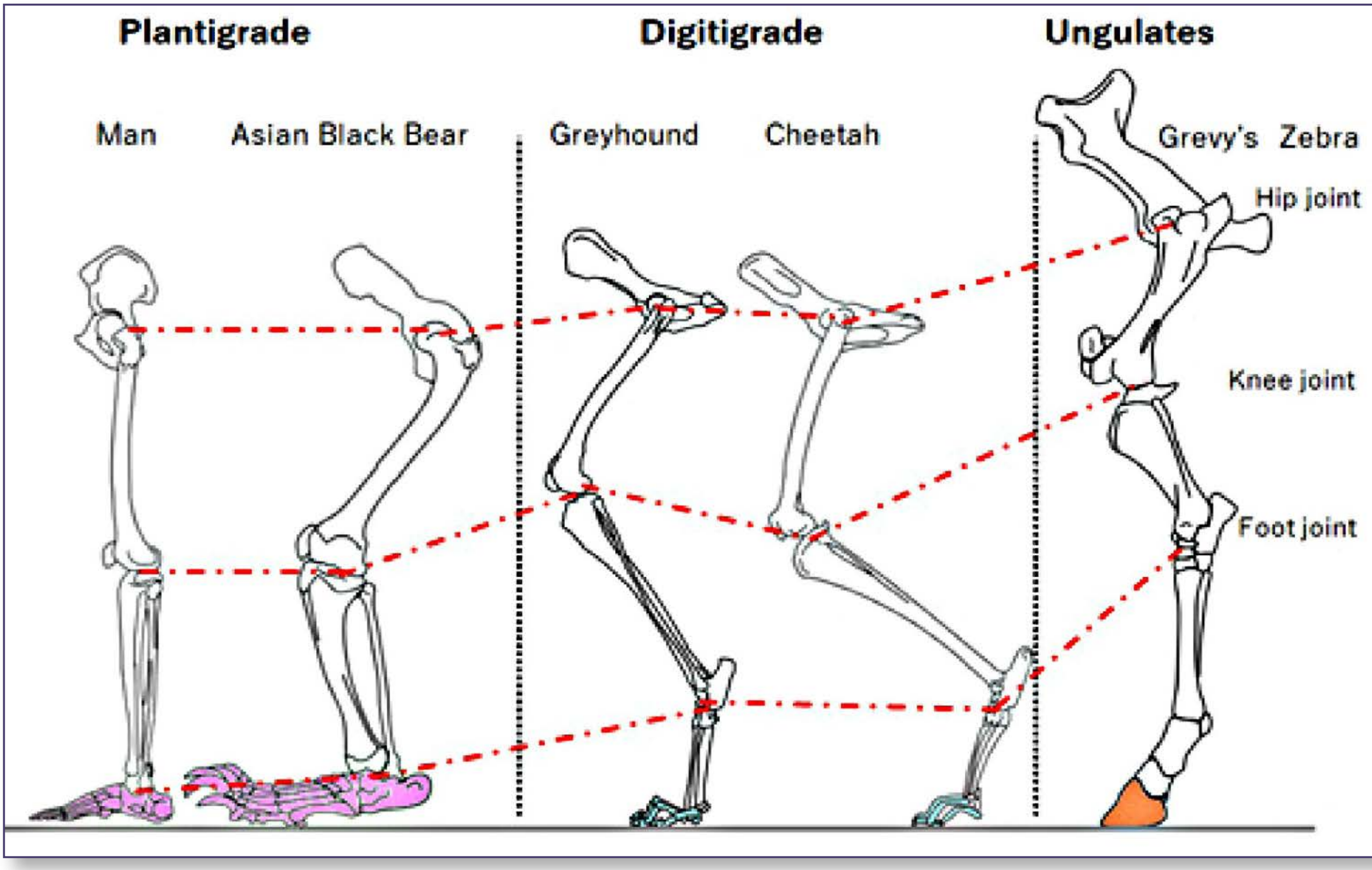

Figure 8. Locomotion of terrestrial mammals.

brace or device or a brace above the ankle, the coverage is more challenging as the reimbursement is every 5 years unless there is dire need and proper justification.

Can One Outgrow TWB?

It is erroneous to think that TWB will be resolved overtime, on its own. We see in the clinic mostly adults with foot/ankle deformities that result from early non- or limited intervention and follow-up to their TWB. However, even young adults who are considered "grown out" of their TWB may only "appear" to have their heels down during gait. This "appearance" is often due to compensation to loss of the dorsiflexion range by pronation at the subtalar joint, abduction at the midtarsal joints. These young adult feet are now rolling over the medial longitudinal arch forcing the foot to rotate outward. When this compensation continues, over time it becomes rigid, and the result is pressure at the medial aspect of the foot causing redness and eventually even skin irritation and callus. This can lead to difficulty in tolerating shoeware and even barefoot walking.

We recently saw a 4-year child with TWB whose feet were severely pronated and everted. Sadly, the treating therapist had told the mother, "Oh, he is not toe walking as much anymore." In our evaluation, we saw a similar scenario: a foot and ankle pronated and everted with feet externally pointed in standing and walking. This child needs to be treated by proper orthotic intervention and should be getting passive and active range of motion exercises and a full home exercise plan should be suggested to the circle of care.

In the presence of a Pes Planus type of foot/ankle with hypermobility and muscle weakness or when the foot architecture is more rigid such as of Pes Cavus, TWB may persist into adulthood. TWB may appear slightly reduced due to the weight of the adult body. In the clinic, we still see some adults with TWB with mild to severe foot and ankle deformities.

A Pes Planus foot where there is hypermobility and a loss of the dynamic and static support structures will result in an incrementally worsening plano-valgus deformity.[11] So, will children grow out of TWB? That answer is murky at best. Rather, what we see is that with time, the body compensates by pronating and distorting the foot/ankle complex.

Does this happen in walking? In the stance phase of the gait cycle an increased foot pronation negatively influences lower extremity sagittal plane biomechanics. Foot pronation increases foot segments' hypermobility and compromises foot lever-arm function during the stance of gait.[12] The joints in the foot distort when they need to be rigid causing an inefficiency in walking. Indeed, adults with a history of TWB often report clinical complaints of foot

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pain or of limited ambulation ability.

Mammal Locomotion Patterns

When trying to understand reasons for TWB, we can look at locomotion of terrestrial mammals which can be classified into 3 types based on contact with the ground (Figure 8). When moving, plantigrade animals keep the heel bone on the ground while digitigrade animals move using only the digits (metatarsals) to touch the ground. Unguligrade mammals walk and run on the tip of digits. Plantigrade is important for stability of body while the 2 other types help produce power, depending on moving speed.[13] This can be interpreted as TWB producing muscle activity to gain power; however, in fact, this type of walking reduces stability in standing and walking.

Treatment Options

When the TWB persists, at any age, treatment options include both conservative and surgical management. Nonsurgical managements are often used as first resort and if not successful, in some cases a surgical approach is considered. Most treatment options focus on improving ROM through stretching and serial casting, gait retraining, botox injections, and bracing treatment. Surgical lengthening at either the Achilles Tendon or gastrocnemius level is aimed at improving ankle ROM. Even when the surgery option is applied, the conservative approach is required to ensure positive result:[14]

- Serial casting to improve ROM.
- Referral to podiatry for biomechanics analysis and assess skin integrity.
- Special shoes and braces – many options from soft garments such as Thera Togs to Sure Step SMO orthotics, or AFOs rigid or hinged. The aim here is to limit the ability to TWB and to allow a person to start placing weight on their heels.
- Physical therapy focusing on enhancing ROM, attention to an improved posture, strength, and gait training. Attention to posture and support to heels when sitting.

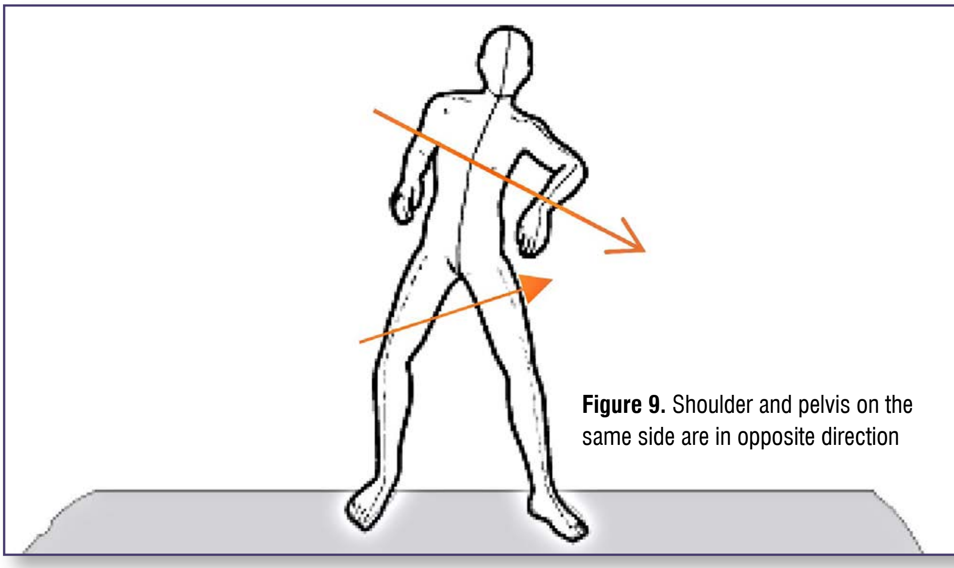

Figure 9. Shoulder and pelvis on the same side are in opposite direction

- Occupational therapy – focusing on sensory processing and integration.
- Botox Injections: the aim here is to reduce the ability of active plantar flexion.
- Surgery: various aims but mostly to elongate short soft tissue.

Research conducted in 2014 found that there was no single treatment option reported as having a long-term effect on the gait of children with ITW; it's important to note, however, that this study was not limited to ASD.[15] Another research study from 2016 focused on TW in individuals with ASD reported the lack of and the need for a structured quantitative test to assess TW in individuals with ASD.[16]

Some suggestions in addition to what was mentioned above:

- Consider and view toe walking and standing behavior as a habit. *Merriam Webster's* defines a habit as "an acquired mode of behavior that has become nearly or completely involuntary."
    - To change a habit means to replace small repeatable, sustainable changes.
- Review first-hand experience reports of individuals with ASD (as noted earlier). One report says: "Lack of grounding or a kind of flowing in a river floating along and there's no ground there's no support, no stability no firm foothold grounding"

Understanding these first-hand experiences of individuals with ASD would call for adding 4 important elements to therapy:

1. Creating an environment for the (individual's) body to feel a sense of stability and grounding.
2. Focusing awareness on bodily sensation by adding support such as boxes, sandbags, and therapist manual guidance. Feet planted on the ground – heel in full contact in sitting. If chair is too high, consider placing a stool under the feet.
3. Relaxation by staying in a position well supported and attending to breath.
4. Repetition of the same practice routine to create proper habit.

How To Start

1. Observe and write or draw a list of postural issues that you see when an individual is sitting, standing, and walking both with shoes and barefoot.
   Sample list of observed issues:
    a. Weight bearing on left lower extremity more than the right
    b. External rotation of lower extremities – origin is from hip
    c. Shoulder and pelvis on the same side are in opposite direction (Figure 9)
2. Repeat this observation step every time you see the individual. This will give your

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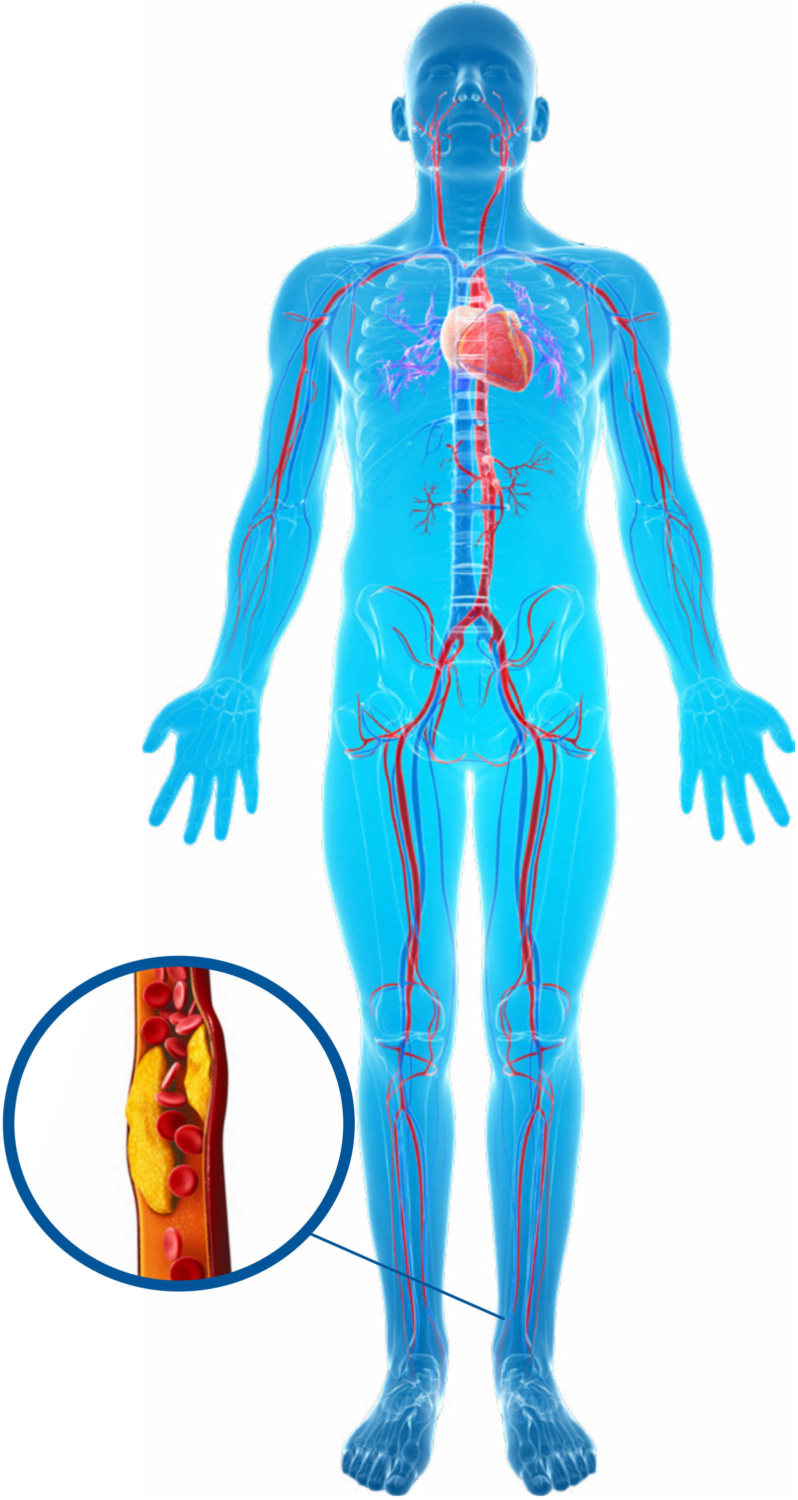
Peripheral Artery Disease

Peripheral Artery Disease (PAD) is a deadly chronic condition that can lead to heart attack, stroke, or amputation.



1 in 3

- » Diabetics age 50+
- » Smokers age 50+
- » Everyone age 70+

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$390 billion

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observation credence depicting intra-rater reliability, a statistics term which means the degree of agreement among repeated tests performed by a single rater.

3. Start thinking of therapy: Share with the individual, their teacher, or caregiver what you see and listen to what they say about what they see and what is their concern.
4. Draw or write down the therapy program, share it with the individual, caregivers, and teachers. The attached drawing will explain some positioning and exercises to practice. Stay with a limited number of exercises, keep their order, and repeat them during sessions. Refine but stay with the same groupings.

What About Our Case Study, Anka?

The disappointment that we experienced comes from the fact that Anka does not use the braces all the time as suggested. Usually, she comes to our clinic with her PLS AFOs on her feet and when we remove them, she still walks with her heels on the ground when barefooted. At home she is without her braces and indeed she goes back to TWB. The benefit from the wear of braces is that she has proper range of motion and has the ability to lower her heel down. We are also disappointed that she does not receive PT at school. We realize it is a difficult task for families to take over the role of the therapist; however, we always encourage, provide, guide, and rehearse a limited Home Exercise Program with the individual's circle of care. We are aware though that often the family is already overwhelmed by the patient's other needs. The revisits and the specific drawing of exercises, or images, allow us to follow the progress and prevent unnecessary changes to the foot and body posture as a whole.

Behavioral Challenges

There is no doubt that working with individuals with behavioral issues can be difficult but understanding their needs, as evidenced in the first-hand experience reported above, certainly helps us to serve our patients as best as we can. Research is clear that attending to postural and walking difficulties should start early and continue throughout the life span. We all have a role to play in making sure that happens.

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Assessment of Physical Activity in Older Adults Across Care Levels

By Astrid Ustad, Karen Sverdrup, Gro Gujord Tangen, Øystein Døhl, Beatrix Vereijken, Pernille Thingstad, and Nina Skjæret-Maroni

Physical activity is a modifiable lifestyle factor that is well established as an important determinant for maintaining function and independence in daily life, and thus is imperative for healthy aging.

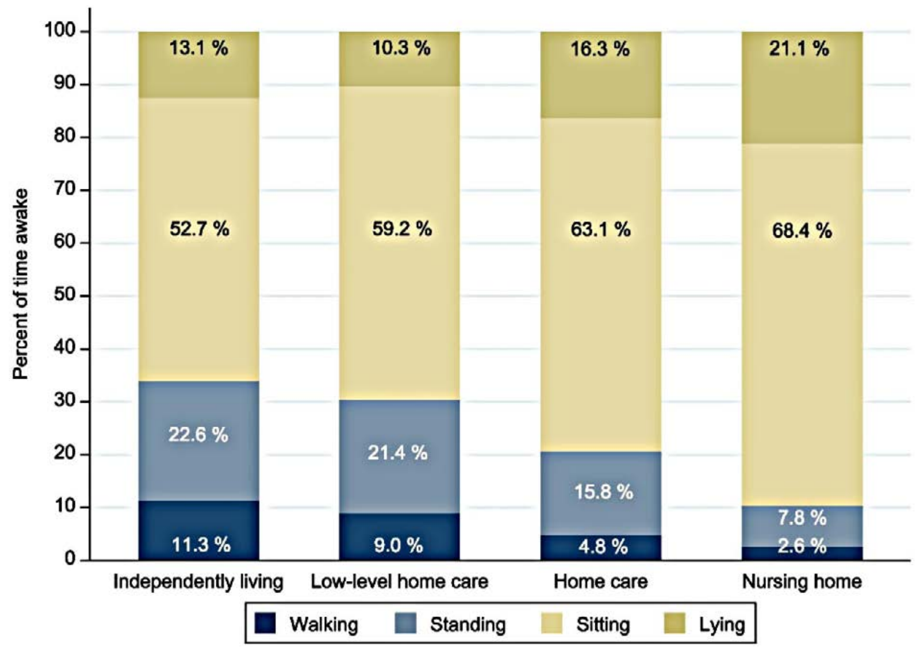

Figure 1. Distribution of activity types in percentage of time awake by level of care.

The 2020 recommendations from the World Health Organization (WHO) highlight that every minute replacing sedentary behavior (SB) with physical activity (PA) of any intensity has health benefits. This has led to a shift from focusing on achieving moderate-to-vigorous PA toward awareness concerning the complementary importance of low-intensity PA and its potential role in reducing sedentary time, which are both feasible and safe for most older adults and have been shown to be associated with lower risk of all-cause mortality. Accurate, clinically meaningful estimates of daily PA among older adults can inform targeted interventions to maintain function and independence. This study describes daily PA in older adults across levels of care as a first step contributing to the limited evidence on potential associations between PA and the use of care services.

Methods

This study used data from the Trondheim 70+ cohort in the population-based Norwegian Trøndelag Health Study (The HUNT Study), which is 1 of the largest health studies ever performed. In total, 1,042 participants age 70 years or older with valid activity data were included. PA was assessed using 2 accelerometers over 7 consecutive days and was classified into PA (walking, standing, running, and cycling) and sedentary behavior (sitting and lying). Data on received care services were retrieved from municipal registers and participants were classified into 4 levels of care: 1) independently living (n = 853, 81.9%); 2) independently living with low-level homecare services (n = 68, 6.5%); 3) recipients of homecare services (n = 62, 6%); and 4) nursing home residents (n = 59, 5.7%). Time spent in the activity types and duration of bouts are presented across levels of care.

Results

Participants' mean age was 77.5 years (range: 70.1–105.4, 55% female). In the groups with higher level of care, participants were older and more likely to be female, had lower physical and cognitive performance, and a larger proportion was diagnosed with mild cognitive impairment (MCI) and dementia. Across levels of care, significant group differences were found in the total time spent in PA, particularly in walking and standing. Indeed, PA was lower with higher age, as were number of walking and active bouts (Figure 1).

Daily PA, duration of active bouts, and number of daily walking bouts were lower for participants receiving higher levels of care. While standing was the dominant type of PA, walking appeared predominantly in short bouts

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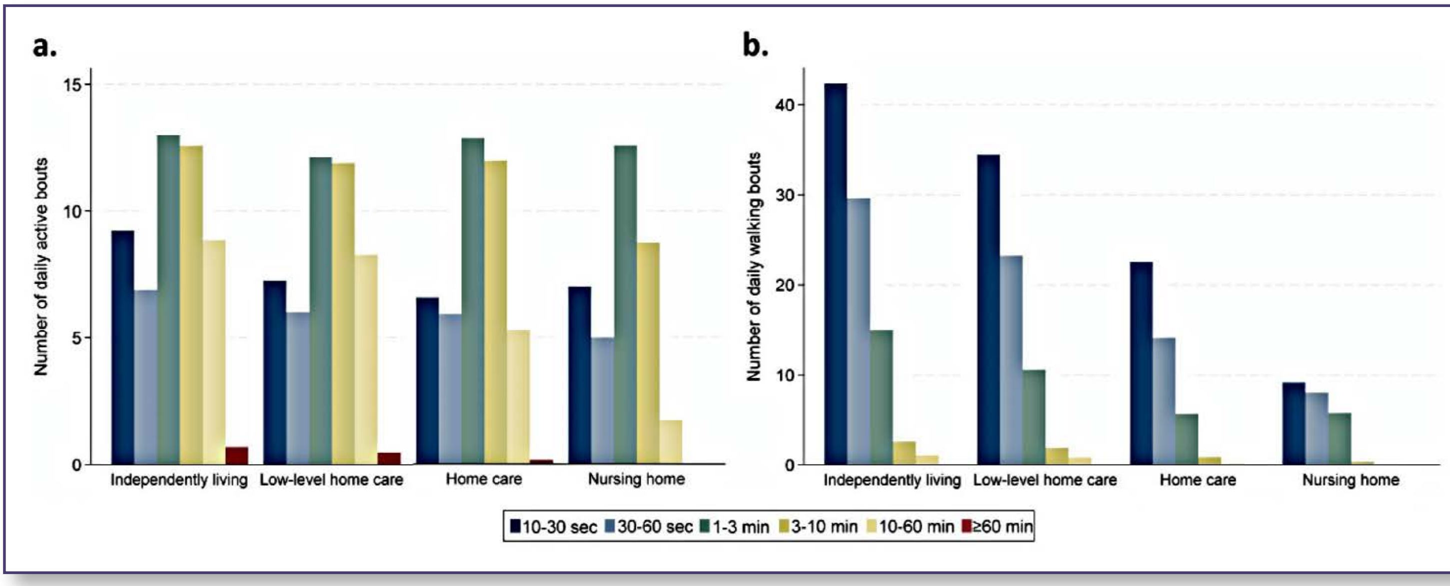

Figure 2. Number of daily active bouts (a) and number of daily walking bouts (b) in categories of bout duration by level of care. Walking bouts contain walking only, while active bouts contain the activity types walking, standing, running, and cycling. Note that the scale of the y-axis is different in the 2 plots.

at all care levels.

The highest number of walking bouts was achieved in the shortest duration category (10–30 seconds) and thereafter steadily fewer bouts in the longer duration categories (Figure 2b). For active bouts (including the activities walking, standing, running, and cycling), most bouts had a duration between 1 and 10 minutes at all care levels (Figure 2a). The daily number of active bouts with longer durations (10–60 and ≥ 60 minutes) were substantially lower at higher care levels.

Discussion

The results in this study revealed that low-intensity activities constitute the primary component of everyday PA in older adults. The total time spent in PA, particularly in walking and standing, were lower at higher care levels compared to independently living older adults, as were duration of active bouts, and number of daily walking bouts. Furthermore, standing was the dominant type of PA and walking appeared predominantly in short bouts at all care levels.

The current study showed that standing was the primary type of PA in older adults. While previous studies mainly focused on intensity or SB, few have classified activity types in older adults using wearable sensors. Classifying physical behavior into activity types can provide accurate estimates of both low- and higher-intensity PA, which can be used to further elaborate recommendations for daily PA in older adults.

The current study introduces a new perspective on how older adults accumulate PA by examining bout durations. By not capturing short bouts of standing and walking, earlier studies likely have underestimated PA, especially since self-reporting low-intensity activities is challenging due to the ubiquitous nature of daily living PA. Additionally, intensity-based cut-point approaches are limited in capturing short bouts, as they analyze data in longer epochs, typically 15–60 s, in contrast to the 5-s windows used in this study. Describing daily PA based on activity types and bout durations could be valuable in guiding future research on interventions aimed at reducing SB by providing more accurate estimates that capture even short bouts of PA.

The current study showed that there are substantial age and sex differences in daily PA in older adults. PA was lower with higher age for both sexes, but while men and women spent nearly equal time walking, women spent more time standing. This finding contributes important information for understanding daily PA among older adults.

Participants in the groups with higher levels of care were older, had worse cognitive and physical function, and were more often female compared to independently living participants. There was no significant difference in daily PA between the low-level homecare group and those living independently at home. Women spend about 35 min more time per day on PA than men. Therefore, the differences in daily PA across care levels are likely influenced by the higher proportion of women at higher care levels. These findings indicate that studies aiming to describe the association between daily PA and care level should consider these factors. As a first step in contributing to the limited evidence on daily PA related to the use of care services, the current study provides clinically relevant measures of PA in older adults. These measures can be further used to investigate potential associations between daily PA and care services.

Investigating not only the total volume of PA but also bout durations provide valuable information about daily activity in older adults, as the study authors observed that daily PA occurs over a wide range of durations. Walking bouts and active bouts, the latter also containing standing, should be seen in context to each other as both provide insight into patterns of accumulated PA in older adults. The study results showed that walking is distributed over many daily bouts and appears predominantly in short bouts lasting less than a minute, consistent with previous studies. The distribution of walking bouts showed a consistent pattern with gradually fewer bouts with longer lengths, although number of bouts were significantly lower with higher levels of care.

This study also showed that episodes of walking are significantly interspersed with episodes of standing in older adults. The lengthened durations of active bouts, and a considerably lower total number of active bouts compared to walking, reveals that periods of standing are a dominant component of upright activities in older adults' daily life. Furthermore, this study showed that prolonged uninterrupted walking does not occur often. Independently living older adults averaged only about 1 daily walking bout lasting longer than 10 minutes, indicating that most older adults either do not engage in prolonged walks or break them up in shorter walking periods.

One of the most prominent differences between care levels was the lower number of walking bouts with higher levels of care, which was consistent across all bout duration categories. A larger number of bouts implies that individuals have more transitions between activity types, reflecting larger variation in daily PA, which previously was observed in individuals with better health status. The observed differences in daily PA variation between care levels might reflect individuals' ability to live independently. This information could be clinically relevant in identifying individuals at risk of functional decline at an early stage and targeting interventions to help them regain or maintain their independence. This study showed that individuals living independently have higher variation in their daily PA than those receiving care services. This suggests that older adults unable to maintain variation in PA may be at risk of requiring care services. The potential of daily PA variation as indicator of functional decline together with targeted interventions focusing on increasing variation by breaking prolonged SB, should be further investigated in longitudinal studies.

Another interesting finding regarding indicators related to functional decline is the observed difference between the low-level homecare group, which receives only safety alarm and/or food service, and the homecare group. The first group did not differ substantially from independently living older adults, neither in total PA volume nor bouts. Although active bouts with durations up to 10 minutes were maintained in the homecare group compared to the low-level homecare group, a significantly lower number of active bouts lasting longer than 10 minutes was observed among those receiving homecare. This difference may indicate that those receiving a higher level of care have stopped going outdoors, and instead engage in everyday indoor activities of shorter durations. Individuals classified in the low-level homecare group may be well-suited for effectively implementing preventive measures. Implementing interventions at this stage aimed at preserving independence, such as increasing PA, may hold great potential for reducing or delaying the need for additional care services. This is crucial for maintaining independence and the quality of life for the individuals and their close ones. According to the findings in this study, prioritizing activity type–specific measures, especially those aimed at maintaining variation and active bout durations at this stage, may hold potential to reduce or delay the need for additional care services.

Conclusions

This study offers novel insights into daily PA patterns and addresses a current evidence gap concerning the free-living PA of older adults across levels of care. The current study shows that low-intensity activities constitute the primary component of everyday PA and advocates for placing larger emphasis on the significant role these activities play in maintaining daily PA at older age. As daily PA, duration of active bouts, and the number of daily walking bouts were lower with higher levels of care, these findings suggest that activity types and bout durations are related to the ability to live independently. These measures may be clinically relevant for assessing PA in older adults. Accurate estimates of daily PA among older adults can be used for evaluation of physical behavior and targeted interventions to maintain function and independence in older adults.

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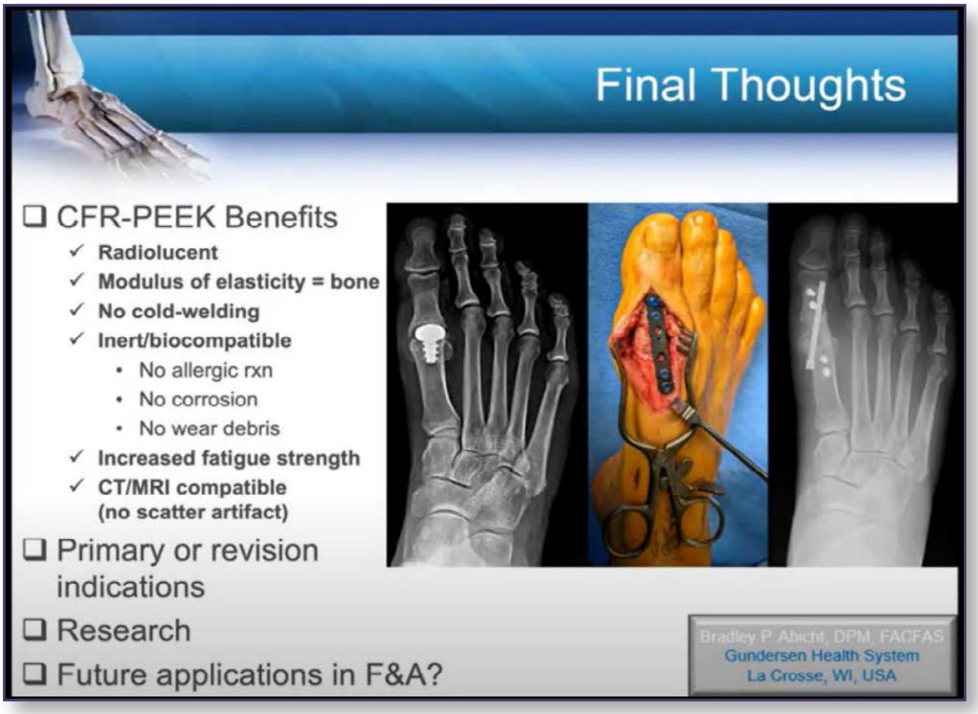
Emerging Radiolucent Technologies and Bone Grafting Techniques

BY BRAD ABICHT, DPM, FACFAS

Innovative advancements are helping foot and ankle surgeons provide more precise procedures, shorten return to life activities time, and improve patient outcomes.



Radiolucent technologies are gaining traction in foot and ankle surgeries due to their significant benefits over traditional methods. These innovations, particularly the use of carbon fiber reinforced polyetheretherketone (PEEK), are revolutionizing how surgeries are performed, offering clearer imaging and better outcomes. This article will highlight the emerging advantages of radiolucent materials in surgical procedures ranging from basic fixes to complex reconstructions.

The primary allure of radiolucent technologies in foot and ankle surgeries lies in their transparency under imaging. Unlike metal plates, which can obscure critical anatomical details, radiolucent materials such as carbon fiber reinforced PEEK allow surgeons clear visualization during and after surgical procedures. This visibility is crucial for accurate placement and adjustment during operations, and it significantly enhances the monitoring of the healing process postoperatively.

Carbon fiber reinforced PEEK is favored not only for its radiolucency but also for its biomechanical properties, which are similar to those of bone. This similarity reduces the risk of stress shielding—a common issue with metal implants where the implant takes on too much stress shielding the bone, thereby hindering optimal healing. Moreover, this material's increased fatigue strength and compatibility with CT and MRI scans make it an excellent choice for internal fixation in orthopedics. Notably, carbon fiber materials do not cause allergic reactions, a common concern with metal-based implants, ensuring a safer postoperative experience for patients sensitive to metals.

Overview of Radiolucent Materials

Radiolucent materials are used in medical applications to allow the clear visualization of body structures during imaging procedures such as X-rays, CT scans, and MRIs. These materials are designed to be permeable to radiation, thus lacking the radio-opacity that metals possess, which typically obscures the view of the underlying biological structures. Common types of radiolucent materials include carbon fiber reinforced polymers (CFRP), such as carbon fiber reinforced PEEK. These materials are valuable in orthopedic surgeries, including those of the foot and ankle, due to their high strength, reduced artifact generation in imaging, and compatibility with the human body.

Carbon fiber reinforced PEEK offers numerous advantages in surgical applications, particularly for bone grafting and surgical treatments of the foot and ankle. One of the main benefits is its radiolucency, which significantly enhances the visibility of bones and joints during and after surgery, aiding in more accurate diagnosis, intervention, and postoperative assessment. Additionally, the material's modulus of elasticity is similar to that of human bone, which minimizes stress shielding—a common problem with metal implants where the implant absorbs too much stress, thereby weakening the bone. Moreover, its inert nature reduces the risk of allergic reactions and inflammatory responses, which are often seen with metal-based implants. Carbon fiber reinforced PEEK also boasts high fatigue strength, which is crucial for the dynamic forces that the lower extremities endure.

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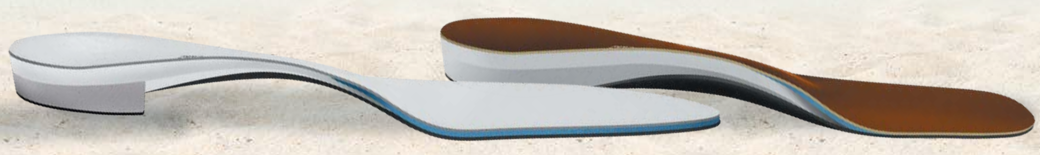

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Clinical Applications and Case Studies

The primary indications for using radiolucent materials in foot and ankle surgeries include scenarios where optimal visualization of bone growth and healing is necessary. This is crucial in complex reconstructive surgeries, fracture fixations, and revisions of previous surgeries. The ability to view the exact placement of bone grafts and monitor the healing process without the interference caused by metal implants presents a clear advantage in treating fractures, osteotomies, and arthrodeses. These materials have been available for other surgical uses for some time, but foot and ankle surgical indications are more recent.

Recent published studies have demonstrated the efficacy of Carbon Fiber Reinforced PEEK in various orthopedic applications. Research points to its high union rates and low complication rates compared to traditional metal plates. Systematic reviews and retrospective case reviews have supported its use, noting comparable, if not superior, outcomes in bone healing and structural stability without the complications associated with metal sensitivities and imaging artifacts.

In practical applications, radiolucent materials have shown significant benefits. For instance, a case involving arthrodesis of the great toe utilized radiolucent plating, allowing unparalleled intraoperative and postoperative visualization of the joint and bone graft (see Case Study 1). This enhanced visibility aids in ensuring correct alignment and promotes more effective healing evaluations during follow-up examinations.

Another case highlighted the use of these materials in revision surgery where metallic implants had failed or caused issues. The radiolucent properties allowed for better assessment and adjustment during the procedure, which is particularly valuable in complex cases where precision is critical for successful outcomes. In revision surgeries involving bone grafting, the ability to monitor the integration of the graft visually can significantly impact the decision-making process regarding weight-bearing and rehabilitation timelines.

Advantages of Radiolucent Technologies

Improved Intraoperative Visualization

Radiolucent materials, such as carbon fiber reinforced polymer (CFRP), offer significant advantages during foot and ankle surgeries by enhancing intraoperative visualization. These technologies allow surgeons to see the bone, joint, arthrodesis, and implant directly through the radiolucent material. This superior visibility facilitates more accurate adjustments during surgery, such as optimal alignment of osteotomies and precise placement of bone grafts. Better intraoperative decisions potentially lead to improved surgical outcomes and reduced need for future corrective procedures.

Enhanced Postoperative Monitoring

After surgery, the ability to effectively monitor bone healing and implant positioning is crucial for patient recovery. Radiolucent technologies are beneficial because they do not produce the scatter artifact seen with traditional metal implants during imaging processes like X-rays, CT scans, or MRIs. As a result, clinicians can observe the healing process more clearly and make informed decisions about postoperative care, such as when to initiate weight-bearing activities or return to daily tasks. This kind of monitoring not only helps in assessing the patient's progress but also in planning any necessary interventions at earlier stages.

Combining Radiolucent Technologies with Bone Grafting

In primary procedures involving foot and ankle surgeries, combining radiolucent technologies with bone grafting has shown to be highly effective. For instance, during arthrodesis of the great toe joint, radiolucent implants facilitate the direct visualization of the bone graft and the fusion site. This ensures that surgeons can verify the correct positioning and integration of the graft material during the initial procedure, leading to better stabilization and alignment of the joint, which are critical for successful bone healing and functional recovery.

The utility of radiolucent technologies becomes even more pronounced in revision surgeries. In complex cases where previous treatments might have failed or led to complications, the transparency of radiolucent materials allows surgeons to accurately assess and place bone grafts, ensuring proper contact and integration. For example, in the revision of a failed bunionectomy, the use of radiolucent technology enables the surgeon to precisely monitor the placement of bone grafts and assess their incorporation into the host bone over time. This can be vital for achieving successful outcomes in surgeries that aim to correct or salvage previous procedural failures.

Challenges and Considerations

While radiolucent technologies offer significant advantages in foot and ankle surgery, they also come with inherent limitations. A notable drawback is the inability of these materials to be contoured or bent during surgery. They must precisely fit the bone's anatomy, which can be restrictive and may require additional modifications by the surgeon. Another issue arises from their radiolucency; while it enhances certain aspects of visualization, it can also complicate the precise placement of hardware as surgeons may struggle to identify the exact location of plates under X-ray or fluoroscopic guidance.

Given these limitations, addressing potential surgical complications becomes crucial. The rigidity of radiolucent materials can lead to difficulties during application, making it essential for surgical teams to have thorough preoperative planning and intraoperative precision. Additionally, the lack of ability to alter the shape of the implants on-the-fly necessitates precise bone modification, which can increase operative time and complexity. To mitigate these issues, surgeons must be highly skilled in using these materials and may benefit from advanced imaging techniques and specialized training sessions to enhance their familiarity with the characteristics and handling of radioluinecent technologies.

Future Directions and Potential Expansions

The field of radiolucent technology in orthopedic surgery is rapidly evolving, with continuous advancements aimed at overcoming current limitations. Future innovations may include the development of adjustable radioluinecent

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materials that can be modified during surgeries to fit individual anatomical variations precisely. Additionally, the integration of these materials with augmented reality and real-time imaging could provide surgeons with enhanced capabilities to see and navigate the surgical site more effectively. This could dramatically improve the precision of implant placement and the overall outcomes of foot and ankle surgeries.

The adoption of radio-opacities in elective foot and ankle procedures presents a unique avenue for research, particularly in the optimization of surgical outcomes and patient recovery processes. Investigating the long-term outcomes of using radiolucent materials compared to traditional metal implants can provide valuable data on the effectiveness and safety of these technologies. Furthermore, exploring patient recovery timelines, the incidence of postoperative complications, and the quality of life post-surgery could offer insights into the broader applications of radioluinecent materials in elective procedures. This research will be crucial in defining the future role of these emerging technologies in foot and ankle orthopedics.

Conclusion

The world of foot and ankle surgery stands on the brink of a transformative era thanks to the integration of radiolucent technologies and advanced bone grafting techniques. Radiolucent materials, particularly carbon fiber reinforced polymers, offer distinct advantages over traditional metal plates, including improved intraoperative visualization, enhanced postoperative monitoring, better elasticity similar to natural bone, and reduced risk of allergic reactions.

These advancements not only enable surgeons to perform procedures with greater precision but also improve patient outcomes by allowing more accurate bone healing assessments and timely interventions during the recovery phase. Additionally, the compatibility of these materials with imaging technologies like CT and MRI reduces the interference that typically complicates diagnostic processes.

As the medical community continues to embrace these innovative technologies, further research and clinical trials will undoubtedly refine their applications, making foot and ankle surgeries safer, less invasive, and more effective.

To learn more about "Emerging Radiolucent Technologies and Foot/Ankle Bone Grafting Techniques," see Brad Abicht's full lecture from the 38th Annual No-Nonsense Seminar, available at https://nononsense2024.lerexpo.com/.

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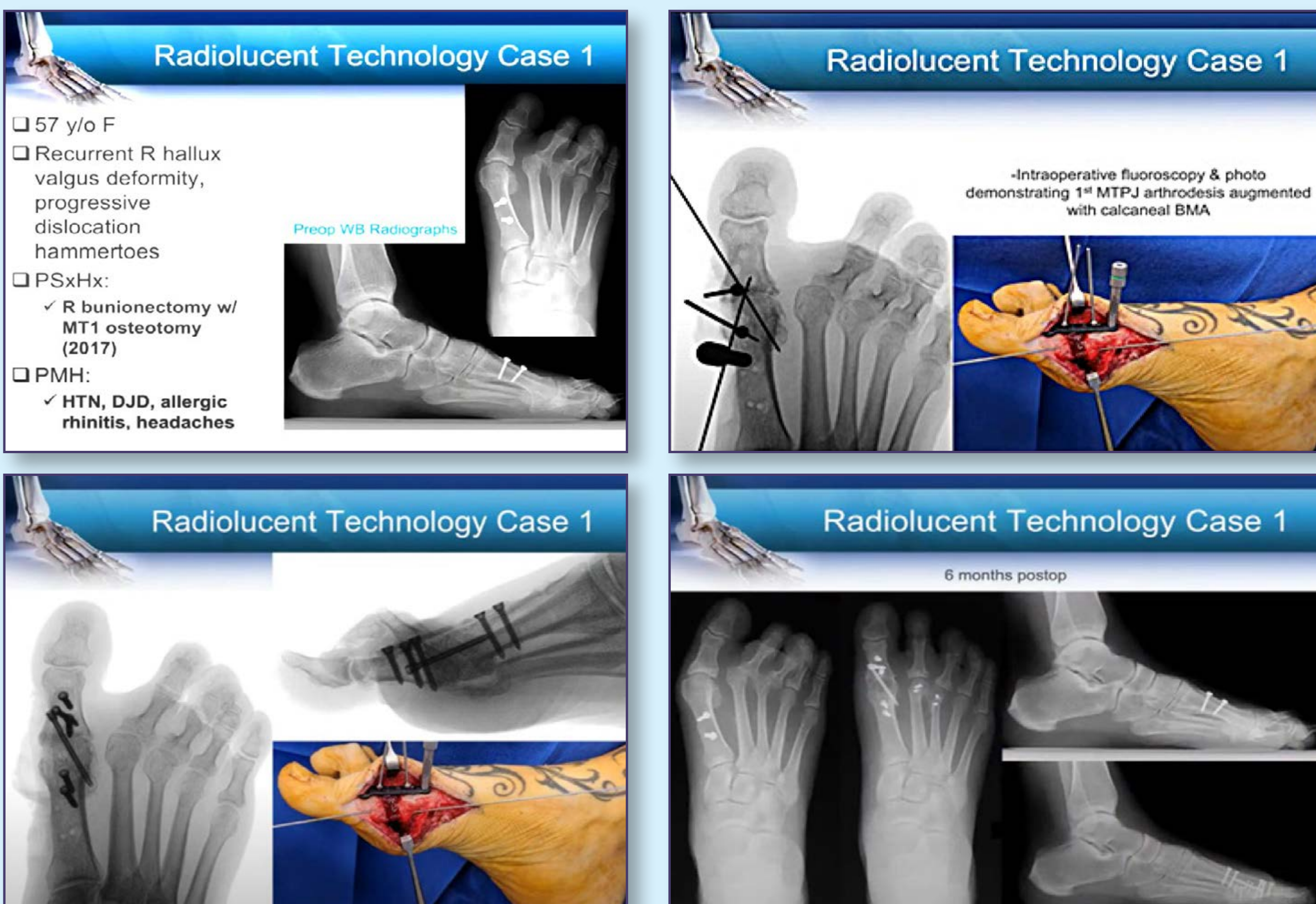
Case Study: Benefits of Radiolucent Technology

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Physical Characteristics Inducing Sever's Disease in Junior Gymnasts

By Kazuaki Kinoshita, Yuichi Hoshino, Naoko Yokota, Masayuki Fukuda, Mika Hirata, and Yuichiro Nishizawa

Sever's disease can be painful and limit young athletes in competitive endeavors. These authors sought to find physical characteristics that could identify those at risk.

Sever's disease, also known as calcaneal apophysitis, is an inflammation of the growth plate in the heels of growing children, typically adolescents. This disease is reported to have an incidence of 2%–16 % among musculoskeletal injuries in children. The pain caused by Sever's disease is often severe enough that the child limps after physical activities to take weight off the affected heel. Most patients with Sever's disease take 3 to 6 weeks to return to painless activity. Athletes with Sever's disease are often disadvantaged in being required to suspend or limit their activities during the injury period.

Sever's disease is an overuse syndrome that could be prevented by some prophylactic measures. Researchers have hypothesized potential intrinsic and extrinsic factors for Sever's disease. Mechanical stress on the calcaneal growth plate is derived from both heel contact pressure and from plantar fascia and Achilles tendon traction force and can be exacerbated by intrinsic factors such as ankle joint stiffness and Achilles tendon tightness. Extrinsic factors that have been reported to exaggerate the pathological mechanical stress on the calcaneal growth plate include high impact activities, footwear, and sports activities performed on hard surfaces. Another extrinsic factor in the development of Sever's disease may involve whole-body physical function. The foot is responsible for maintaining balance through forming a supportive surface and for absorbing shock, based on kinetic chain principles. Sever's disease affects the proximal segment of the foot, which can make stabilization difficult during static and dynamic activity, with subsequent proximal segment function reciprocally affecting whole body function.

Sever's disease occurs frequently in gymnasts. Two cohort studies have reported that gymnastics-related inversion ankle injuries are the most frequent lower extremity injuries, followed by Sever's disease. Gymnastics involves the repetitive, jarring impact of vault takeoffs and dismounts from a variety of heights and tumbling activities. Additionally, gymnasts must perform barefoot without the support of shoes that attenuate impact during jumping and running, and, thus, Sever's disease is highly disadvantageous for gymnasts. Empirical evidence concerning risk factors or the physical characteristics in Sever's disease remains limited. Therefore, this prospective cohort study, using functional tests, aimed to determine which physical characteristics of junior gymnasts might contribute to the development of Sever's disease. We hypothesized that specific risk factors related to the development of Sever's disease would be identified. The secondary objective is to explore the relationship between these identified characteristics and the incidence of Sever's disease in gymnasts. Through elucidating these relationships, the findings aim to inform preventive strategies and optimize the management of Sever's disease in this athletic population.

This article has been excerpted from "Physical characteristics inducing Sever's disease in junior gymnasts," by the same authors. It was originally published in Heliyon. 2024;10(19):e38717. doi: 10.1016/j.heliyon.2024.e38717. Editing has occurred, including the renumbering and removal of tables and figures, and references have been removed for brevity. Use is per CC Attribution 4.0 International License.

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Table 1. Measured values of the two groups of each item (Foot alignments).

		No-symptom group (65limbs)			Sever group (9 limbs)			p	
The ratio of arch height	%	13.9	±	2.1	12.4	±	1.6	.04	*
LHA	Angle	7.5	±	2.3	7.3	±	1.8	.86	

(Mann–Whitney U test).
*: $p < 0.05$.

Table 2. Measured values of the two groups of each itemFunctional balancing tests).

		No-symptom group (65limbs)			Sever group (9 limbs)			p
One-legged Standing	1/cm	28.1	±	8.1	27.0	±	7.2	.70
SEBT anterior	%	94.3	±	9.6	87.0	±	5.5	.03
SEBT posteromedial	%	103.4	±	11.0	100.0	±	11.0	.39
SEBT posterolateral	%	111.2	±	11.5	104.9	±	13.2	.14
Figure-of-8 hop	Sec	11.4	±	.9	11.7	±	.9	.64

(Mann–Whitney U test).
*: $p < 0.05$.

Table 3. Logistic regression analysis.

	B	Standard error	Significance probability	Exp(B)	95 % confidence interval	
					Lower limit	Upper limit
SEBT Anterior	−12.967	5.418	.017	.000	.000	.095
Ratio of arch height	−.577	.249	.020	.561	.345	.915

Methods

This study included 74 limbs from 37 junior gymnastics athletes, of whom 15 were males and 22 were females. The mean age, height, weight, and Rohrer index of the participants were 11.5 ±1.7 years, 140.1 ±10.5 cm, 33.7 ±8.4 kg, and 120.3 ±8.1, respectively. The participants engaged in approximately 18 hours of training per week. During this period, they did not use an orthosis to prevent Sever's disease. We excluded individuals who had heel pain at the start of the study, ankle injuries and/or complaints, those with neurological or orthopedic abnormalities, individuals who complained of pain during the measurements, and those unable to complete the measurements due to the risk of further injury.

The evaluation items were 4 basic demographic data: age, height, weight, and Rohrer index; 3 flexibility measurements: generalized joint laxity (GJL), heel buttock distance (HBD), and ankle dorsiflexion angle (knee flexion position); 2 foot alignments: arch height ratio and leg heel angle; 5 trunk function tests: side bridge test, abdominal muscle function, back muscle function, back and abdominal muscles strength ratio; and 3 functional balancing tests; 1-legged standing, Star Excursion Balance Test (SEBT), and figure-of-8 hop. All the items were measured by the same person. All data are expressed as mean ±standard deviation.

The study observed gymnasts with Sever's disease over 6 months from the first date of measurement. Those diagnosed at a medical institution as having Sever's disease were classified into a Sever's disease group, and those who did not have pain or who had not been diagnosed at a medical institution were classified into a no-symptom group. Participants were required to seek medical attention if they experienced pain lasting more than 2 weeks. If, during that examination, Sever's disease was ruled out, they were categorized into the no-symptom group. This study incorporates elements of a cohort study rather than a cross-sectional design. The Mann–Whitney U test was used to compare the 2 groups. A stepwise logistic regression analysis was used to identify factors involved in Sever's disease at 6 months, with the above mentioned factors as explanatory variables, and the odds ratios and 95% confidence intervals were calculated. The explanatory variables were narrowed down in advance by using the variable increase or decrease method. The input or removal values at this time were $P = 0.20–.25$. Statistical analysis was performed using IBM SPSS Statistics for Windows, (IBM Corp., Armonk, NY, USA). The statistical significance level was set at $P < 0.05$.

Results

The Sever's group comprised 9 limbs (males, n = 2 limbs; females, n = 7 limbs). One male and 2 females exhibited symptoms bilaterally. Therefore, the total number of individuals in the Sever group was 6. The arch height ratio was significantly lower in the Sever group (12.4 ± 1.6 %) than in the no-symptom group (13.9 ± 2.1 %) (Table 1). The anterior SEBT values were significantly lower in the Sever's group (87.0 ± 5.5 %) than in the no-symptom group (94.3 ± 9.6 %) (Table 2). There were no other significant differences between the 2 groups. Logistic regression analysis was conducted to identify the independent relationships between Sever's disease and suspected risk factors. The explanatory variables were first narrowed down through applying a refining process. The result included

3 items (Rohrer index, arch height ratio, and anterior SEBT values). Finally, the arch height ratio and anterior SEBT values were applied to the model (Table 3).

Discussion

The main study findings indicated that there was a lower arch height ratio and reduced dynamic postural balancing function, as evaluated using the anterior SEBT, among the junior gymnasts who developed Sever's disease.

In this study, no difference or association was observed in the ankle dorsiflexion angle. Instead, the Sever's group had a greater ankle dorsiflexion angle approaching significance. Potential intrinsic factors include a limited range of ankle dorsiflexion motion. The calcaneal growth plate and apophysis are situated in an area susceptible to high stress from the plantar fascia and Achilles tendon and may be affected by increased tension on the calcaneus. Sever's disease has also been reported to be caused by tightness of the Achilles tendon. But Rolf et al questioned the existence of excessive tightness in the triceps surae. The reason is that in studies of patients with Sever's disease, multiple raters typically evaluate the dorsiflexion of the leg, which reduces the uniformity of measurement and the reliability of the results. Furthermore, there are significant differences between the current study and previous literature in the methods used to assess ankle dorsiflexion angle. In previous studies examining ankle dorsiflexion angle and heel pain, participants were assessed with the knee extended. Since knee extension biases the gastrocnemius muscle, while knee flexion has a Soleus bias, it is possible that tightness in the gastrocnemius muscle may have gone undetected in the case group. Therefore, some studies suggest an increase in ankle dorsiflexion due to the increased range of motion as a causative factor not previously considered. Further discussions are required in the future.

The findings of lower arch height ratio are corroborated by prior research. Sever's disease also occurs more commonly in children who overpronate and involves both heels in more than half of the patients. Sever and Lewin reported that there may be a slight amount of protonation present, which should be addressed. A lower arch height ratio can cause excessive stress on the surrounding soft tissues, causing muscle imbalance and abnormal joint alignment, as well as overuse syndromes. Clinicians often use postural-control assessments to evaluate the risk of injury, the initial deficits resulting from injury, and the level of improvement after intervention for an injury.

This study yielded a new finding that the decreased SEBT values are associated with Sever's disease, which has not been previously reported. The SEBT values are used as an index of dynamic postural control (ie, a greater distance reached indicates better dynamic postural control). High school basketball players who had a lower SEBT during the preseason were 7 times more likely to sustain ankle injuries. Particularly, it has a significant relationship with chronic ankle instability. Previous studies have reported that dynamic balance may better reflect the sensorimotor control mechanisms required for sports-specific tasks. Moreover, most overuse injuries occur in the lower extremities, especially the knees, ankles, and feet. The most typical is reported to be Sever's disease. Additionally, previous studies have reported that the anterior SEBT reach significantly affects ankle dorsiflexion angle and plantar sensory function compared to the posteromedial and posterolateral SEBT reaches. In this study, there were no problems with the ankle dorsiflexion angle, which is considered to be related to dynamic balance. This suggests that dynamic balance is likely involved.

The overlap between these 2 factors may be important in the development of Sever's diseases. It has been reported that a decrease in the arch height ratio and SEBT leads to decreased lower limb support, neuromuscular control, proprioceptors, and static and dynamic balance abilities. This may lead to overuse of the muscles around the foot and ankle joints. The arch is controlled by both local stabilizers and the global movers of the foot. Local stabilizers are plantar intrinsic muscles that originate and insert on the foot; they have small moment arms and serve primarily to stabilize the arches. Many of these muscles are attached to the heel. Global movers have larger moment arms, are prime movers of the foot, and provide some stability to the arch. These typical Achilles tendons are attached to the heels. In other words, the overuse of these muscles can damage the heel. Furthermore, an unstable lower leg increases the risk of direct damage to the heel. The main theory in the literature on the pathophysiology of Sever's disease is that it is an overuse syndrome due to repetitive microtrauma caused by increased traction on the apophysis. So, these 2 factors put strain on the calcaneus.

Conclusions

Though limited by its small sample size, this study provided valuable data on the characteristics contributing to the development of Sever's disease in junior gymnasts. The main study findings indicated that there was a lower arch height ratio and reduced dynamic postural balancing function, as evaluated using the anterior SEBT, among the junior gymnasts who developed Sever's disease. In this study, there was no observed decrease in the commonly mentioned ankle dorsiflexion angle. These results will contribute to the prevention of Sever's disease. However, further research is needed to demonstrate the effectiveness of Sever's disease prevention. Future research will continue to unravel the complex interactions between Sever's disease and various factors, aiming to discover superior treatment strategies.

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New & Noteworthy

Noteworthy products, association news, and market updates

MUSCLE RETENTION CREAM

Skin healthcare company EX Healthcare recently announced the launch of dermaFIT, a muscle retention cream. This revolutionary body cream combats muscle loss by harnessing the power of the body's own microRNAs. This cutting-edge product utilizes the power of exosomes to deliver therapeutic benefits directly to the muscles. The journey begins with the application of dermaFIT to the skin. Once the exosomes are secreted in the skin, they travel through the bloodstream to reach their target destination—the muscles. Upon reaching the muscle tissues, the exosomes deliver specific bioactive molecules that help in maintaining muscle mass and preventing atrophy. This vegan muscle cream has been dermatologist-tested, and is non-irritating and free from any harmful ingredients.

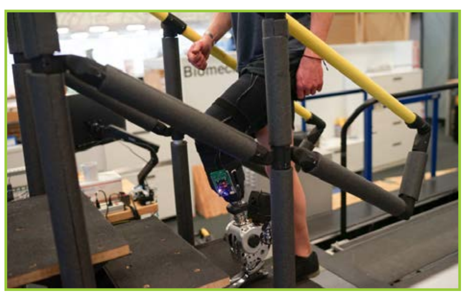
EX Healthcare

exhealthcare.com

PROSTHESIS DRIVEN BY NERVOUS SYSTEM ALLOWS NATURAL GAIT

Using a new type of surgical intervention and neuroprosthetic interface, Massachusetts Institute of Technology (MIT) researchers, in collaboration with colleagues from Brigham and Women's Hospital, have shown that a natural walking gait is achievable using a prosthetic leg fully driven by the body's own nervous system. The surgical amputation procedure, known as the agonist-antagonist myoneural interface (AMI), reconnects muscles in the residual limb, which allows patients to receive proprioceptive feedback about where their prosthetic limb is in space.

Most limb movement is controlled by pairs of muscles that take turns stretching and contracting. During a traditional transtibial amputation, the interactions of these paired muscles are disrupted, making it very difficult for the nervous system to sense the position of a muscle and how fast it's contracting—sensory information that is critical for the brain to decide how to move the limb. People with this kind of amputation may have trouble controlling their prosthetic limb because they can't accurately sense where the limb is in space. Instead, they rely on robotic controllers built into the prosthetic limb. These limbs also include sensors that can detect and adjust to slopes and obstacles.



"This is the first prosthetic study in history that shows a leg prosthesis under full neural modulation, where a biomimetic gait emerges," said Herr. Image courtesy of Hugh Herr and Hyungeun Song.

To try to help people achieve a natural gait under full nervous system control, Hugh Herr, PhD, a professor of media arts and sciences, co-director of the K. Lisa Yang Center for Bionics at MIT, and an associate member of MIT's McGovern Institute for Brain Research, and his colleagues began developing the AMI surgery several years ago. Instead of severing natural agonist-antagonist muscle interactions, they connect the 2 ends of the muscles so that they still dynamically communicate with each other within the residual limb. This surgery can be done during a primary amputation, or the muscles can be reconnected after the initial amputation as part of a revision procedure.

For this study, the researchers compared 7 people who had the AMI surgery with 7 who had traditional transtibial amputations. All of the subjects used the same type of prosthesis with a powered ankle as well as electrodes that can sense electromyography signals from the tibialis anterior the gastrocnemius muscles. These signals are fed into a robotic controller that helps the prosthesis calculate how much to bend the ankle, how much torque to apply, or how much power to deliver. The researchers tested the subjects in several different situations: level-ground walking across a 10-meter pathway, walking up a slope, walking down a ramp, walking up and down stairs, and walking on a level surface while avoiding obstacles.

In all of these tasks, the people with the AMI neuroprosthetic interface were able to walk faster—at about the same rate as people without amputations—and navigate around obstacles more easily. They showed more natural movements, such as pointing the toes of the prosthesis upward while going up stairs or stepping over an obstacle, and they were better able to coordinate the movements of their prosthetic limb and their intact limb. They were also able to push off the ground with the same amount of force as someone without an amputation. These natural behaviors emerged even though the amount of sensory feedback provided by the AMI was less than 20% of what would normally be received in people without an amputation. They also experienced less pain.

SEAMS IN CLOTHING CAN CAPTURE BODY MOVEMENT

Everyday clothing may soon be able to capture and record body movements according to new research from the Universities of Bristol and

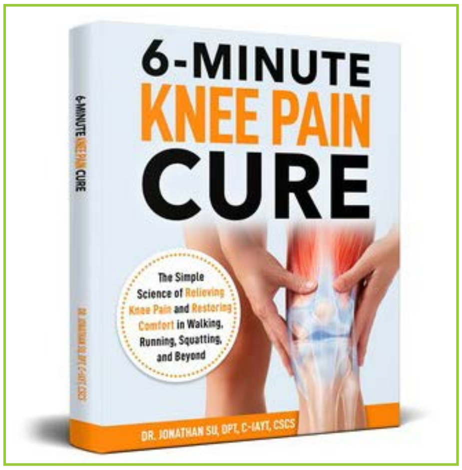
SeamSleeve is a novel sensing mechanism that uses powered seams as sensing channels, retaining traditional fabric design benefits for comfortable and robust motion capture. (a) The researchers empirically evaluate and compare different designs to determine the optimal placement of seams and sensing channels; (b) they demonstrate that their approach can effectively train and classify arm movements; (c) they propose SeamSleeve for rehabilitation exercises beyond the clinic. Image courtesy of Olivia Ruston.

Bath, United Kingdom. Harmless low voltages are passed through conductive threads that are stitched into garment seams to create electrical circuits. Their resistance changes with the movement of the wearer's body. The work opens up new possibilities to make digital clothing that senses and captures movements much more accurately than is possible using current phones and smart watches. The work lays the foundations for e-textile designers and clothing manufacturers to create cutting edge garments that could enhance exercise, physiotherapy, and rehabilitation.

"We've shown that common overlocked seams in standard garment constructions can do a good job of sensing movement," said Professor Mike Fraser, PhD, of the University of Bristol's School of Computer Science "The design avoids the need for a separate power source by pairing the seam with a charging coil, drawing the energy wirelessly from a mobile phone placed in the pocket. This means advanced motion sensing garments could be made without altering existing manufacturing processes."

Additionally, Fraser said that he and his colleagues have shown that smartphone apps using advanced artificial intelligence techniques can use this movement data to match body movement to specific postures or gestures such as physiotherapeutic exercises.

NEW PUBLICATION ADDRESSES KNEE PAIN



6-Minute Knee Pain Cure: The Simple Science of Relieving Knee Pain and Restoring Comfort in Walking, Running, Squatting, and Beyond, was written by Jonathan Su, DPT, C-IAYT, CSCS, a physical therapist, yoga therapist, and fitness coach, who drew from his own experience and research overcoming knee pain decades after a serious injury. The guide is aimed at helping people alleviate knee discomfort naturally, without relying on medication. The author stresses the need for a knee maintenance routine, which functions like regular car maintenance, to tune up the knee. The publication offers an easy-to-follow 3-step system that delivers fast and effective knee pain relief for individuals of all ages and fitness levels in the comfort of home. It features more than 100 illustrations and provides access to numerous online videos to ensure that every step is easy to follow.

6-Minute Knee Pain Cure
sixminutefitness.com

UD-DEVELOPED BIOMATERIALS APPROVED FOR WOUND MANAGEMENT PRODUCTS

The U.S. Food and Drug Administration has approved 2 new wound management products that include patented hydrogels invented by University of Delaware (UD) material scientist Darrin Pochan, PhD, and Joel Schneider, PhD, a former UD faculty member now at the National Cancer Institute. The unique hydrogel materials are made of peptides—the building blocks of proteins—that self-assemble to form a 3D matrix and are compatible with living cells. The consistency of jelly, the unique materials are useful for a variety of applications.

Gel4Med, a Harvard University-based biomaterials engineering company, licensed 4 patents related to the technology via UD's Office of Economic Innovation and Partnerships (OEIP) in 2018. The company incorporated the UD-developed hydrogels into 2 products, G4Derm and G4Derm Plus, that have been intentionally designed to speed healing by combatting bacterial and fungal infection while simultaneously promoting tissue regrowth.

Image courtesy of Jeffrey C. Chase/UD.

Gel4Med is currently piloting the products in healthcare settings in the United States. According to Gel4Med CEO Manav Mehta, the needs in the clinic are vast and advances in biomaterials are needed. Antibiotic resistance is a huge problem. Wound closure also is a major issue. Traditionally, pharmaceutical companies and wound care companies approach these problems independently.

"But a wound is a 2-sided problem," Mehta said. "You have an infection problem, which is managing the bioburden, but also a wound-closure problem."

Current antimicrobials on the market are generally designed to sterilize everything they encounter. Placed on an open wound, this means that while killing bacteria, an antimicrobial also may exert a toxic effect on healthy cells that are participating in wound closure.

This is where G4Derm and G4Derm Plus are different—and where UD's technology makes it mark.

The UD-patented biomaterials included in the products are inherently antimicrobial and flow in such a way that allows the product to reach wounds with crevasses and uneven topography, often missed by traditional sheet form products. The product has the ability to remain in place over long time-periods, too, before gradually being absorbed by the body, creating a natural scaffold on which tissue can regenerate and grow. Another feature that set the UD-developed biomaterials apart is that the hydrogel extrudes as a liquid and immediately regains its 3D structure at the molecular level after application.

Mehta pointed to Pochan and Schneider's approach and intellect around peptide design as critical to Gel4Med's ability to advance such an industry-disrupting solution. "It's not just an innovation problem that they solved from a broad-spectrum antimicrobial perspective, but also other aspects from a commercialization standpoint, such as the ability to produce the hydrogels economically at-scale and the ability to build a simplified supply chain due to this innovative materials science approach," he said.

Peptides and proteins typically degrade and break down under high heat, but the UD-developed peptides fold appropriately and are thermostable, allowing them to resist degradation at very high temperatures, an advantage over other materials in the marketplace. This allows them to be sterilized using steam as a final step in manufacturing, which enables a potentially safer and more environmentally friendly manufacturing approach, as well as the ability to use the product in various settings of care from operating rooms to the bedside.

HANGER VENTURES INVESTS IN BIONIC POWER

Hanger Ventures, a Hanger, Inc. business whose primary objective is to advance orthotics and prosthetics innovation and improve patient outcomes, recently announced its debut investment in Bionic Power, a Canadian-based firm. A developer of active lower body smart orthotic devices that enhance personal mobility, Bionic Power is raising Series A Round funding, with Hanger Ventures committing as the lead investor.

"We look forward to contributing clinical research, along with technical and commercial expertise, to bring innovative solutions to the market that have the potential to meet an unmet clinical need and improve the quality of life for individuals with mobility challenges," said James Campbell, PhD, Hanger Ventures president and Hanger, Inc. chief clinical officer.

Bionic Power devices enhance walking abilities for children and adults with neuromuscular diseases and conditions, including cerebral palsy, spina bifida, and stroke. The collaboration provides Bionic Power with financial funding and services for product development, clinical trials, and go-to-market support.

COMPRESSION MASSAGE BOOTS

The Recovery Pro Full Leg Compression Massage Boots (FT-091A&FT-109A) offer powerful and upgraded features to cater to a wide range of needs. Whether it's for a pre-workout warmup or a post-workout quick recovery, these boots deliver precise and comfortable massages. They effectively reduce pain and soreness, improve blood circulation, alleviate muscle stiffness, and reduce swelling. This device is designed for intense athletes, regular exercisers, or elderly individuals in need of daily relaxation.

Key upgrades include the following: The pressure range has been upgraded from 30–110mmHg to 40–150mmHg. There are 12 intensity levels compared to the previous 7 levels, allowing users to choose more precise massage intensities according to their needs and preferences. Time options have been expanded from 4 to 10 settings. The standby time has been extended from 3 hours to 3.5 hours.

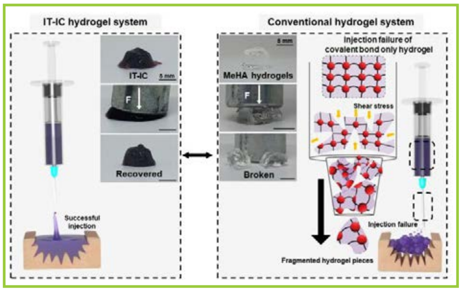
Fit King
fitkingshop.com

BIOMATERIAL TECHNOLOGY, REHABILITATION MEDICINE TO AID IN MUSCLE/NERVE REGENERATION

Researchers from the Institute of Basic Science (IBS) in South Korea have developed a novel approach to healing muscle injury by employing "injectable tissue prosthesis" in the form of conductive hydrogels and combining it with a robot-assisted rehabilitation system.

Let's imagine you are swimming in the ocean. A giant shark approaches and bites a huge chunk of meat out of your thigh, resulting in a complete loss of motor/sensor function in your leg. If left untreated, such severe muscle damage would result in permanent loss of function and disability.

Traditional rehabilitation methods for these kinds of muscle injuries have long sought an efficient closed-loop gait rehabilitation system that merges lightweight exoskeletons and wearable/implantable devices to aid the patient through the process of recovering sensory and motor functions linked to nerve and muscle damage. Unfortunately, the mechanical properties and rigid nature of existing electronic



This new hydrogel system (it-ic) can protect the gel from destruction by external forces. In conventional covalently crosslinked hydrogels (eg, methacrylated hyaluronic acid, referred to as meha), fragmentation occurs due to the destruction of covalent bonds during the injection process, but it-ic hydrogels maintain covalent bonds due to stress dissipation with multiple bonds containing biphenyl structure and allow injection into narrow areas. Image courtesy of IBS

materials are incompatible with soft tissues, leading to friction and potential inflammation, and thus stalling rehabilitation.

To overcome these limitations, the IBS researchers turned to a material commonly used as a wrinkle-smoothing filler, called hyaluronic acid. Using this substance, an injectable hydrogel was developed for "tissue prostheses," which can temporarily fill the gap of the missing muscle/nerve tissues while it regenerates. The injectable nature of this material gives it a significant advantage over traditional bioelectronic devices, which are unsuitable for narrow, deep, or small areas, and necessitate invasive surgeries.

Thanks to its highly "tissue-like" properties, this hydrogel seamlessly interfaces with biological tissues and can be easily administered to hard-to-reach body areas without surgery. The reversible and irreversible crosslinks within the hydrogel adapt to high shear stress during injection, ensuring excellent mechanical stability. This hydrogel also incorporates gold nanoparticles, which gives it decent electrical properties, allowing for the transmission of electrophysiological signals between the 2 ends of injured tissues. In addition, the hydrogel is biodegradable, so an additional surgery is unnecessary.

With mechanical properties akin to natural tissues, exceptional tissue adhesion, and injectable characteristics, researchers believe this material offers a novel approach to rehabilitation.

Testing in rodent models has proved to be promising. The research team is currently working to develop new materials for nerve and muscle tissue regeneration that can be implanted in a minimally invasive manner. They are also exploring the potential for recovery in various tissue damages through the injection of the conductive hydrogel, eliminating the need for open surgery.

RAPID CRACK REPAIR CREAM

SkinIntegra's Rapid Crack Repair Cream has received the Seal of Approval from the American Podiatric Medical Association (APMA), which recognizes worthy products that can contribute to foot health. Originally developed for people with diabetes suffering from infection-prone cracks to their feet, Rapid Crack Repair Cream has proven to be efficacious in providing fast relief to many hard-to-treat skin-cracking conditions thanks to its comprehensive patented skin barrier repair formula. What sets this product apart from others is its fast-acting formula. The cream is designed to provide immediate relief upon application, soothing discomfort from deep cracks. Its patented skin barrier composition precisely mimics the content of the skin barrier and works in harmony with the skin. Its lightweight texture allows for quick absorption, making it suitable for use on various parts of the body, including hands, feet, elbows, and knees.

SkinIntegra
442/226-2262
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TENS UNIT

The AUVON PT1 Pro TENS Unit Muscle Stimulator offers a safe, non-invasive, and cost-effective method of body pain relief via 8 customizable modes and 40 levels of intensity and a precise control knob. This cutting-edge device allows users to gradually adjust stimulation strength to activate specific natural pain gate mechanisms to relieve body pain more safely. Individual pain relief needs vary widely, leading to the development of personalized pain management approaches. The device is also distinguished by its 600mAh rechargeable battery that can withstand up to 60 hours of continuous treatment per charge and a variety of American-made TENS gel pad in different sizes for focused treatment on different body parts. Two or 4 pads can be used at once, accommodating users' specific needs. This be user-friendly device is was designed to provide a simple and easy-to-use solution for professional pain relief at home.

Auvon
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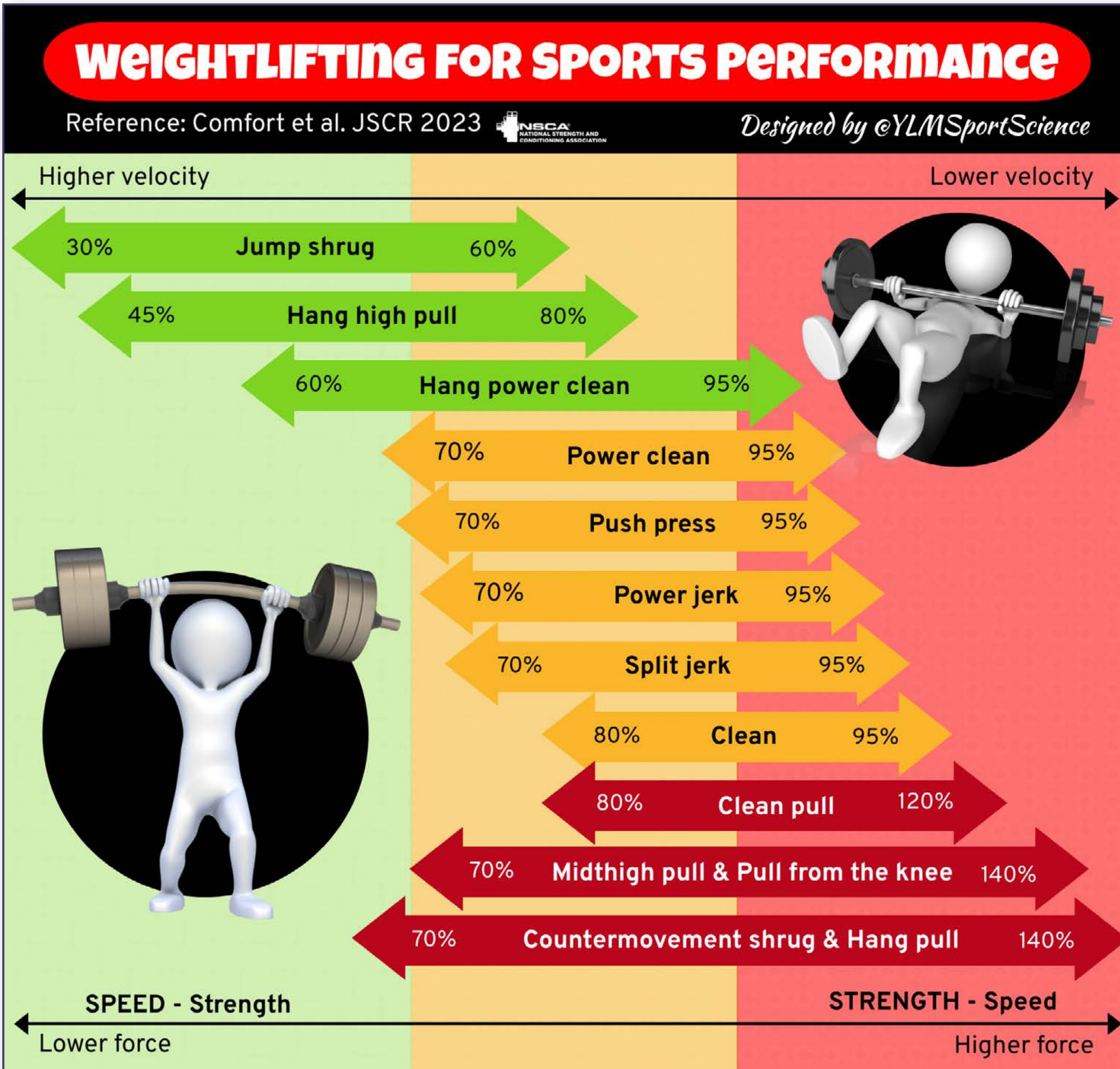

Source: Comfort P, Haff GG, Suchomel TJ, et al. National Strength and Conditioning Association Position Statement on Weightlifting for Sports Performance. J Strength Cond Res. 2023;37(6):1163-1190. doi: 10.1519/JSC.0000000000004476.