

Project Notes:

Project Title:

Name: Nair, Prisha

Note Well: There are NO Short-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

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Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
Arduino Implementation	Adel	With Adel and Online Resources (Adafruit, youtube videos)	12/05/25
CAD	Ryan	In Fusion and With Ryan	01/28/26
Machine Learning	Kaggle Course	In the ML Course	01/04/26

Literature Search Parameters:

These searches were performed between 08/29/2025 and 12/20/2025.

List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
PubMed	"Orthotic Devices"[MeSH] AND "Ankle Injuries"[MeSH] AND "Rehabilitation"	I got 178 results and am currently going through them to filter out any lit reviews and irrelevant studies.

Tags:

Tag Name	

Article #1 Notes: Template

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	
Source citation (APA Format)	
Original URL	
Source type	

Keywords	
#Tags	
Summary of key points + notes (include methodology)	
Research Question/Problem/Need	
Important Figures	
VOCAB: (w/definition)	
Cited references to follow up on	
Follow up Questions	

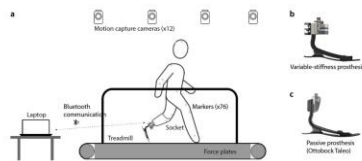
Article #1 Notes: Variable-stiffness prosthesis improves biomechanics of walking across speeds compared to a passive device

Article notes should be on separate sheets

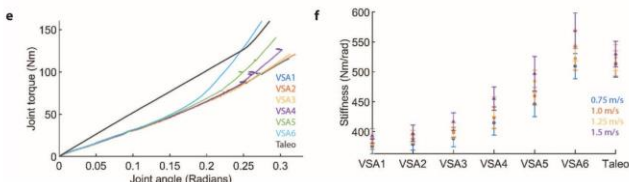
Source Title	Variable-stiffness prosthesis improves biomechanics of walking across speeds compared to a passive device
Source citation (APA Format)	Rogers-Bradley, E., Yeon, S. H., Landis, C., et al. (2024). Variable-stiffness prosthesis improves biomechanics of walking across speeds compared to a passive device. <i>Scientific Reports</i> , 14, 16521. https://doi.org/10.1038/s41598-024-67230-3
Original URL	https://www.nature.com/articles/s41598-024-67230-3
Source type	Scientific Journal Article
Keywords	Prosthesis, biomechanics
#Tags	
Summary of key points + notes (include methodology)	<p>There are three main types of unilateral transtibial amputee prosthetics, passive/stiff prosthetics, powered prosthetics, and quasi-passive prosthetics. Passive prosthetics are too stiff for many walking speeds due to the waste of elastic potential energy which causes increased pressure on the prosthetic leg and decreased pressure on the collateral leg, creating stress and increasing chances for future knee problems, while powered prosthetics do the opposite and still cause similar problems. On the other hand, quasi-passive prosthetics can use microprocessors to control the stiffness of the joints and mimic the biological foot. The researchers tested a microprocessor controlled variable stiffness prosthetic that weighs 945 g, has a computer adjustable nominal stiffness range of 375–569 Nm/rad, and has a build height of 162 mm on 7 subjects, 4 speeds, and 6 stiffnesses. They had the subjects walk on a treadmill and compared the ankle push off power and center of mass push off to a standard passive prosthetic with a pre-determined stiffness. The results showed that the prosthetic side had less pressure, and the collateral side had more pressure, which they could control across multiple speeds.</p> <p>Notes Taken While Reading:</p> <ul style="list-style-type: none"> • Ankle push off power plays a role in healthy walking (center of mass acceleration and swing phase initiation which is the push off to swing your

	<p>leg forward to walk) and accounts for 45% of leg power</p> <ul style="list-style-type: none"> • People with below the knee amputations have been shown to have less ankle push off power in the amputated leg and therefore increased pressure in the collateral limb which contributes to knee problems in the future • Powered prosthetics have been shown to do the opposite and take too much pressure off the collateral leg, causing problems as well. Plus, there is only one model available on the market which only 5% or less of people use due to increased cost. • There is a third category that is shown in this study which is called quasi-passive. Which uses microprocessor controlled joint position control in during swing phase. It is the sweet spot between the above models • Prosthetic ankles are stiffer than biological ones specifically at slower walking speeds • The researchers want to compare a microprocessor controlled, variable stiffness ankle foot prosthesis to a standard passive one at different walking speeds (the former is heavier than the latter) • This newer model puts less pressure on the non-amputated foot and contributes more to center of mass acceleration • We want less force on the non-amputated leg and more on the amputated one to balance the workload (which they did) • In the biological ankle joint stiffness is important as the ankle behaves like a spring • During running humans vary joint stiffness to adapt to ground surfaces of varying terrain. • Decreasing forefoot bending stiffness increases energy storage and return and increases peak prosthetic power. • The researchers used computer controllable, parallel-sliding composite leaf springs. This structure reduces maximum bending stress for a given deflection. • The researchers hypothesized, regardless of the increased mass and mechanical energy loss due to sliding contact forces at the spring interface, autonomous microprocessor controlled variable stiffness prosthetic will demonstrate an increased energy return, and center of mass push off. This will improve the biomechanics of walking across multiple walking speeds. • A passive prosthetic is too stiff for most walking speeds and is wasting elastic potential energy storage and return. • The experimental prosthetic weighs 945 g, has a computer adjustable nominal stiffness range of 375–569 Nm/rad, and has a build height of 162 mm • The subjects walked on a treadmill at 0.75 m/s to 1.5 m/s and 6 different stiffnesses • They compared it to a standard passive prosthetic with a mass of 463g • The results showed that the prosthetic side had less pressure, and the collateral side had more pressure, which means the prosthetic worked compared to the stiff one.
Research Question/Problem/Need	<p>Can a microprocessor controlled variable stiffness prosthetic demonstrate an increased energy return and center of mass push off across different speeds compared to a standard passive prosthetic with a pre-determined stiffness?</p>

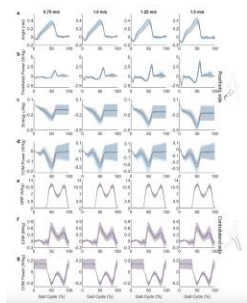
Important Figures



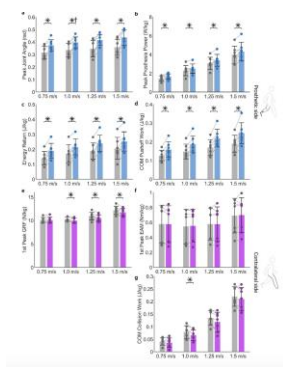
This figure shows the methodology and the build of the two types of prosthesis side by side for comparison.



(e) compares the torque-angle slope to the 6 stiffnesses. As the stiffness setting is increased, the slope of the torque-angle curve becomes steeper, indicating that a larger torque is required to achieve the same change in ankle angle, or conversely, a smaller change in angle occurs for a given torque. (f) mean stiffness (similar data to (e), different graph)



The figures present gait cycle curves for the same biomechanical metrics, highlighting differences throughout the walking cycle. The variable stiffness prosthesis produces greater dorsiflexion, higher positive push-off power, and improved energy return on the prosthetic side, while reducing contralateral limb loading during stance transitions.



The bar graphs compare metrics between the passive prosthesis and the variable-

	<p>stiffness prosthesis across different walking speeds. It shows the variable stiffness device significantly improved prosthetic side joint angle, power, energy return, and push off work, while reducing contralateral ground reaction forces and collision work at some speeds.</p>
<p>VOCAB: (w/definition)</p>	<p>Variable-Stiffness Prosthesis (VSA) - A prosthetic ankle-foot device that can change its stiffness in real time through microprocessor control, allowing it to better mimic the adaptive stiffness of the biological ankle during different walking speeds.</p> <p>Center of Mass (CoM) Push-off Work – The mechanical work generated by the prosthetic side during the push-off phase of walking, representing how effectively the prosthesis contributes to forward propulsion.</p> <p>Ground Reaction Force (GRF) - The force exerted by the ground on the body during walking</p> <p>Energy Storage and Return (ESR) Prosthesis – A type of prosthetic foot that stores energy during the stance phase and releases it at push-off, but typically with less efficiency and adaptability compared to variable stiffness or powered devices.</p> <p>Quasi-Passive Prosthesis – A prosthesis that uses microprocessor control and mechanical adjustments without providing net positive power during stance, making it lighter and less energy demanding than a fully powered prosthesis.</p>
<p>Cited references to follow up on</p>	<ol style="list-style-type: none"> 1. Glanzer, E. M. & Adamczyk, P. G. Design and validation of a semi-active variable stiffness foot prosthesis. <i>IEEE Trans. Neural Syst. Rehabil. Eng.</i> 26, 2351–2359 (2018). 2. Russell Esposito, E., Aldridge Whitehead, J. M. & Wilken, J. M. Step-to-step transition work during level and inclined walking using passive and powered ankle-foot prostheses. <i>Prosthet. Orthot. Int.</i> 40, 311–319 (2016). 3. Major, M. J., Twiste, M., Kenney, L. P. & Howard, D. The effects of prosthetic ankle stiffness on ankle and knee kinematics, prosthetic limb loading, and net metabolic cost of trans-tibial amputee gait. <i>Clin. Biomech.</i> 29, 98–104 (2014).
<p>Follow up Questions</p>	<ol style="list-style-type: none"> 1. How does long-term use of a variable-stiffness prosthesis affect the development of secondary musculoskeletal conditions, such as knee osteoarthritis, compared to passive devices? 2. What are the metabolic energy cost differences between variable-stiffness prostheses, passive prostheses, and powered prostheses during prolonged walking? 3. How does user comfort, adaptability, and preference for variable-stiffness prostheses vary across different populations (e.g., age, weight, activity)?

	level, sex)?
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Article #2 Notes: Short term and long-term effects of joint taping and bandaging on balance, proprioception and vertical jump among volleyball players with chronic ankle instability

Article notes should be on separate sheets

Source Title	Short-term and long-term effects of ankle joint taping and bandaging on balance, proprioception and vertical jump among volleyball players with chronic ankle instability
Source citation (APA Format)	Alawna, M., & Mohamed, A. A. (2020a). Short-term and long-term effects of ankle joint taping and bandaging on balance, proprioception and vertical jump among volleyball players with chronic ankle instability. <i>Physical Therapy in Sport</i> , 46, 145–154. https://doi.org/10.1016/j.ptsp.2020.08.015
Original URL	https://www.sciencedirect.com/science/article/abs/pii/S1466853X20305228?via%3Dihub
Source type	Journal Article
Keywords	Orthotic ankle brace
#Tags	
Summary of key points + notes (include methodology)	Ankle injuries are the most common among athletes, with 20% of acute sprains becoming chronic and leading to balance and movement issues. Proprioceptive training and external supports like ankle taping are often recommended for patients with chronic ankle instability (CAI), through research on their effectiveness has shown mixed results due to small sample sizes and short-term focus. To address this, a randomized controlled trial studied 130 volleyball players with CAI, dividing them into taping, bandaging, and placebo groups. Participants were tested for proprioception, balance, and vertical jump over baseline, immediate, 2-week, and 2-month intervals. Results showed that both taping and bandaging significantly improved balance and jump height after two weeks and

two months, though immediate effects were limited to vertical jump. Overall, the study suggests that prolonged use of external support can enhance proprioception, stability, and performance in athletes with CAI, with taping and bandaging providing similar benefits.

Notes Taken While Reading:

- Ankle injuries are the most common among athletes (80%) and individuals
- 20% of acute ankle sprains turns into chronic ones which affects balance and movement
- Any balance training program should include for patients with chronic ankle instability (CAI) should include **proprioceptive training**
- Rehabilitators recommend ankle taping for improving proprioception and balance for patients with CAI because it helps with adjusting abnormal excessive movements that occur during sports (**ankle plantarflexion or excessive varus stress**) and improves the firing rate of cutaneous mechanoreceptors (better balance control and ankle function).
- Contradicting studies on the effectiveness of ankle taping since some studies say there is improvement in perceived stability and balance control while others say there is non-significant effects on ankle functional instability.
- Those studies have moderate methodological quality and limited evidence since they have only focused on immediate effects with a small number of participants
- **Hypothesis: Prolonged use of ankle taping during athletic activities produces more significant increases in proprioception, balance, and vertical jump among volleyball players with CAI.**
- The researchers used a **single-blinded randomized controlled design** was used where the participants didn't know their specific role (treatment group) in the study.
- They used statistics to calculate the sample size needed, 95 patients, with an extra 18 to compensate for people who will drop out.
- 130 volleyball players were examined (18-30 years old) who were diagnosed with CAI (they had at least 2 acute ankle sprains in the past 6 months, and it is accompanied by normal symptoms)
- They were excluded if they reported previous lower body surgeries in the past year, leg length discrepancies, or disorders which led to balance impairment.
- They were divided into 3 groups randomly (by college staff using **dice sample randomization method**): the taping group (33), bandaging group (33), and placebo taping or control group (34)
- Outcome measures were proprioception, balance, and vertical jump.
- Dominant leg was determined which should be used to (2 of 3): kick a ball, draw a diamond figure on the ground, use the leg to step over a spider toy
- All measurements were taken four times before applying external

supports and considered baseline measurements

- The intervals for measurements were immediately after applying the external supports, 2 weeks after applying it, and 2 months after removing the external support.
- Proprioception measurements (3 steps): (1) the participant was seated on a chair with their eyes closed and their ankle was tested in 4 positions (10 dorsiflexion, neutral position, 10 plantarflexion, and 20 plantarflexion) each one time for 5 sec with a custom wood plank (2) walk freely beside the therapist with their eyes closed for 10 min (3) sit in a high chair with feet off the floor with eyes closed and do the previously learned ankle positions alone and the range of motion was measured with a universal goniometer and absolute error was calculated with the preformed and previously recorded ROM.
- Before starting measurement procedures, participants were asked to practice the exercise 6 times to reduce the **learning-error effect**. They did 3 trials in each of the 3 directions with a 5 min rest period between each trial
- Therapist measured reaching distance:
 - Measuring how far participants can reach with one leg while standing on the other.
 - Grid center: the point where the person's stance foot (the supporting foot) stays
 - Maximal reaching point: farthest point the reaching foot can reach without losing balance
 - The therapist used a tape measurement to measure the distance between the grid center and maximal reaching point
 - Attempts were canceled when: the participant put too much weight on the swing leg OR lifted the stance leg off the center point and the trial had to be repeated
 - Normalized reach distance: $(\text{average reach distance} / \text{leg length}) \times 100$
 - The equation gives a percentage of leg length
- Vertical Jump Height Measurements
 - Done by vertical jump tester
 - First, they were asked to reach to the highest point they could by standing still
 - Then, they did a countermovement jump to try to touch the highest point they could
 - The reaching distance at each step was recorded
- Treatment Procedures
 - Taping, bandaging, and placebo taping
 - They were applied during athletic training activity 2-3 hours/session and 3-5 training sessions/week
 - Every two weeks (during the assessment the external support was removed and replaced.
- Ankle Taping
 - Hard preventative **Zinc Oxide Tape**

- Before taping: wash feet with water and soap and dry, non-adhesive gauze pads to prevent blisters, pre-wrap adhesive tape from arch to bottom of calf
- Taping:
 - Anchor Tape: tape wrapped around the lower shin as a base point where other tape will attach
 - Stirrup Tape: neutral position foot, start on the inside ankle, run tape under foot, pass behind heel, come back up the other side, do this twice for extra support. (cover the back 1/3 of the foot)
 - Locking Tape: Another strip of tape is wrapped around the shin again above the ankle bones to prevent the stirrup tape from coming off during the activity.
 - Applied by a physical therapist and they wore sports shoes over the ankle tape
- Ankle Placebo Taping
 - Same type of tape was used
 - Just applied 4 inches long strip was applied to the side of the ankle and participants were told this will improve ankle function
- Ankle bandaging
 - 4 in wide elastic bandage was used
 - Wash and dry feet
 - Wrapped in a figure 8 style around the ankle
 - Sports shoes over the bandage
- Statistical Analysis
 - Data coding and blinding
 - Faculty administrator coded the participants files (Reduce bias)
 - Type of analysis
 - Intention to treat analysis: included all participants as originally assigned to groups even if some dropped out or didn't fully follow the treatment (for realistic results)
 - Statistical Tests
 - Within each group (intervention vs. Control)
 - Repeated measures MANOVA to see how outcomes changed over time
 - Between groups (comparing intervention vs. control)
 - Independent MANOVA to check if the treatment effect different between groups across time
 - Outcome measures
 - Data was collected at three time points (start, 2 weeks, and 2 months)
 - For each variable measured (like reaching distance) they calculated mean and standard deviation.
 - Comparing baseline characteristics
 - To make sure the two groups were similar at the start
 - Pearson chi-squared test was used for categorical

	<p>variables (gender, presence/absence of previous pain, diabetic history)</p> <ul style="list-style-type: none"> • Independent t-test was used for continuous variables (leg length, years of playing experience) <ul style="list-style-type: none"> ▪ Significance Level cutoff: $p < .05$ • Non-significant differences between groups in age, height, leg length, weight, BMI, and playing years • Ankle joint ROM, vertical jump, and reaching distance were normally distributed in both groups • Non-significant changes between the baseline and then immediately after the application of the external support. • Normalized reaching distance significantly increased between baseline, 2 weeks, and 2 months • Vertical jump height increased significantly immediately after applying the external support • Overall... <ul style="list-style-type: none"> ○ Both taping and bandaging improved jump height and balance measures after 2 weeks and after 2 months (compared to baseline) ○ Right after applying external support, improvements were not yet significant for balance measures since the benefits took time to show ○ Compared to the control group, both external supports worked better overtime ○ Taping and bandaging worked about equally well. • Immediate improvement was seen in vertical jump height only and in order to see significant improvement in proprioception, then the tape or bandage must be applied over a period of time.
<p>Research Question/Problem/Need</p>	<p>Can prolonged use of ankle taping during athletic activity produce more significant increases in proprioception, balance, and vertical jump among volleyball players who have Chronic Ankle Instability?</p>

Important Figures

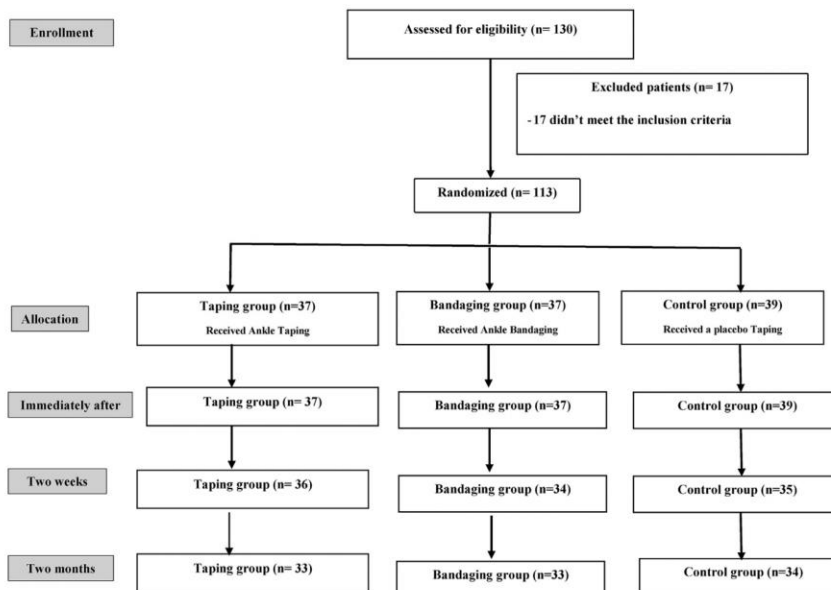
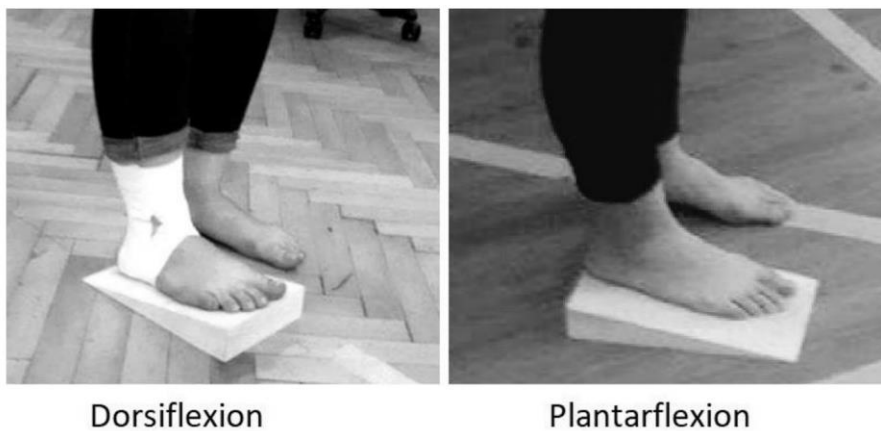


Fig. 1. Patients flow chart.

Figure 1: A flow chart of how participants were chosen and separated into groups as well as how well they stuck through the study for two months, actively tracking how many people were lost.



Dorsiflexion

Plantarflexion

Fig. 2. Custom - made wooden sloops.

Figure 2: The custom wooden planks were used to test proprioception as the participants learned the positions of the foot and had to replicate it after 10 minutes of walking to test range of motion.

Table 1
Physical characteristics of patients in all groups.

Items	Taping group	Bandaging group	Placebo group	P
	Mean ± SD	Mean ± SD	Mean ± SD	
Age (yrs.)	22.25 ± 2.96	23.56 ± 4.25	22.95 ± 3.24	>0.05
BMI	23.25 ± 1.01	24.30 ± 1.11	23.89 ± 1.85	>0.05
Male	18	19f	19	>0.05
Female	15	14	15	>0.05
Leg Length (inches)	37.15 ± 1.78	36.26 ± 2.13	36.84 ± 2.05	>0.05
Playing years (yrs)	8.54 ± 1.65	9.11 ± 2.41	8.97 ± 3.56	>0.05
Smoking	3	2	5	>0.05
Non-smoking	30	31	29	>0.05

SD: standard deviation, P: probability, yrs: years. *: significant.

Table 1: Compares baseline characteristics for Taping, Bandaging, and Placebo. All p-values > 0.05 meaning no significant differences between groups. So, results aren't biased by initial differences.

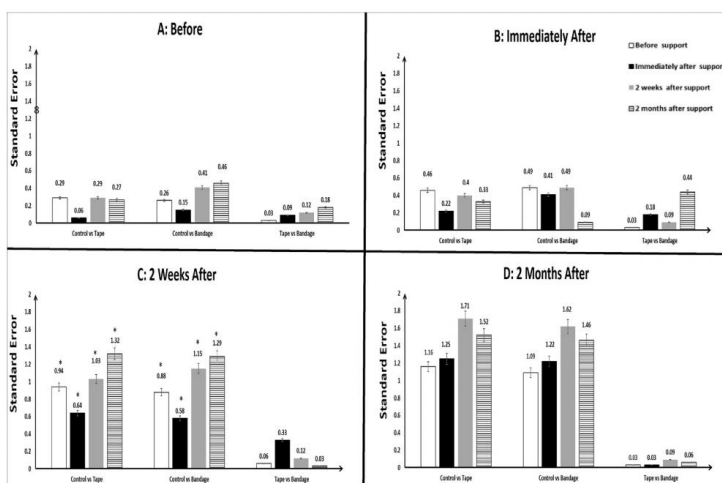


Fig. 3. Independent measure MANOVA between groups (Control, Tape, Bandage) at the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support *: Significant.

Figure 3: Graphs show proprioception error values. At 2 weeks and at 2 months taping and bandaging groups had lower error values (improved significantly).

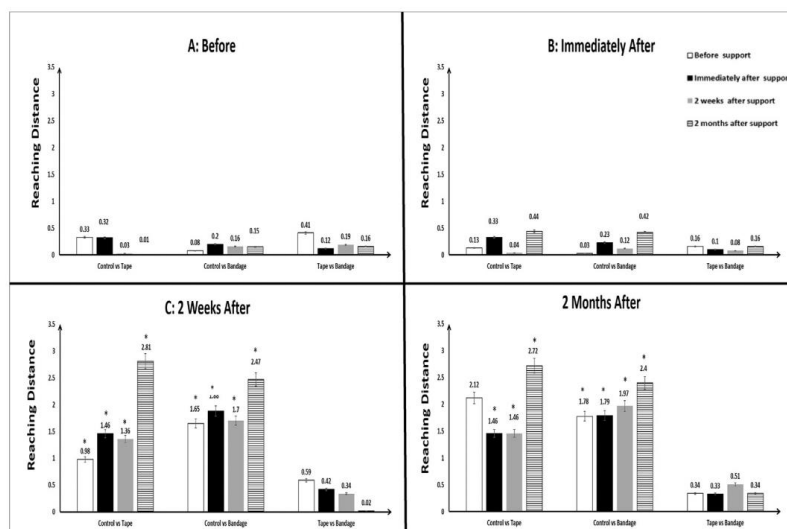
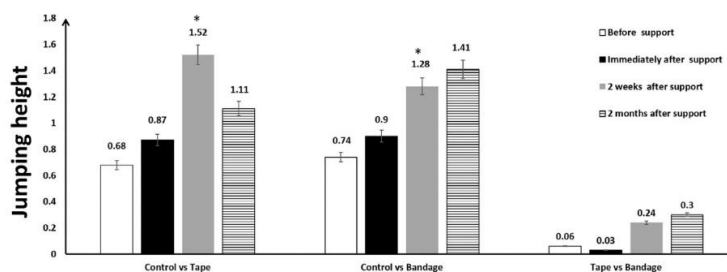


Fig. 4. Independent measure MANOVA between groups (Control, Tape, Bandage) at the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support.

Figure 4: Bar graphs of balance test scores across time. At 2 weeks and at 2 months both taping and bandaging groups improved more than the control.



Independent measure MANOVA between the intervention and control groups (Control, Tape, Bandage) at the baseline (Before support), immediately after support, 2 weeks after support, and 2 months after support.

Figure 5: Bar graph of vertical jump results. At 2 weeks and at 2 months the taping and bandaging are both significantly higher than the control.

VOCAB: (w/definition)

Proprioceptive Training: uses exercises to improve your sense of body position and movement, enhancing balance, coordination, and stability

Zinc Oxide Tape: primarily used by athletes to prevent injuries, protect wounds and help speed up healing time

Single-blinded randomized controlled design: a research design where one group, either the participants or the researchers, is unaware of which treatment or intervention each subject is receiving.

Ankle plantarflexion: a movement of the ankle joint where the foot moves

	<p>downward and the toes point away from the body</p> <p>Excessive varus stress: a force that pushes the knee or other joints inward, potentially causing injury to the ligaments on the outside of the joint</p>
Cited references to follow up on	<ol style="list-style-type: none"> 1. Bici, S., Karatas, N., & Baltaci, G. (2012). Effect of athletic taping and kinesiotaping® on measurements of functional performance in basketball players with chronic inversion ankle sprains. <i>International Journal of Sports Physical Therapy</i>, 7(2), 154-166. 2. Bunton, E. E., Pitney, W. A., Cappaert, T. A., & Kane, A. W. (1993). The role of limb torque, muscle action and proprioception during closed kinetic chain rehabilitation of the lower extremity. <i>Journal of Athletic Training</i>, 28(1), 10e20.
Follow up Questions	<ol style="list-style-type: none"> 1. Would the results differ across different sports or intensity levels, since volleyball players may have, unique ankle demands compared to runners, basketball players, or soccer players? 2. How sustainable are the benefits after stopping taping or bandaging; do athletes maintain improved proprioception and balance long-term, or do the effects diminish without continued use? 3. Could newer adaptive materials or smart braces outperform traditional taping and bandaging, especially in providing real time support during high-intensity movement?

Article #3 Notes: Four Week Ankle-Rehabilitation Programs in Adolescents Athletes with Chronic Ankle Instability

Article notes should be on separate sheets

Source Title	Four-Week Ankle-Rehabilitation Programs in Adolescent Athletes with Chronic Ankle Instability
Source citation (APA Format)	Cain, M. S., Ban, R. J., Chen, Y.-P., Geil, M. D., Goerger, B. M., & Linens, S. W. (2020, August 1). Four-week ankle-rehabilitation programs in adolescent athletes with chronic ankle instability. <i>Journal of Athletic Training</i> , 55(8), 801-810. https://nata.kglmeridian.com/view/journals/attr/55/8/article-p801.xml
Original URL	https://nata.kglmeridian.com/view/journals/attr/55/8/article-p801.xml
Source type	Journal Article
Keywords	"Orthotic Devices"[MeSH] AND "Ankle Injuries"[MeSH] AND "Rehabilitation"
#Tags	
Summary of key points + notes (include methodology)	<p>This study tested whether resistance band training, BAPS Board exercises, or a combination of both was most effective for adolescents with chronic ankle instability (CAI), a common issue after ankle sprains that reduces function and activity levels. Using a randomized controlled design, researchers measured static and dynamic balance, functional performance, and patient reported outcomes (PROs). All three intervention groups improved significantly compared to controls, with gains confirmed by ANOVAs, effect sizes, and in some cases surpassing the minimal detectable change (MDC), meaning changes were real, and clinically meaningful. However no single program, including the combined approach, consistently outperformed the others, and PROs only showed improvement over time rather than between groups. The key takeaway is that simple, low-equipment rehabilitation programs (resistance bands or BAPS) can effectively improve balance and function in adolescents with CAI in high school settings but combining them does not provide added benefit.</p> <ul style="list-style-type: none"> • Resistance band and balance board tech improves the condition of patients with Chronic Ankle Instability (CAI) BUT should we combine the two exercises? • The objectiveness was to test the effectiveness of 3 rehabilitation programs on balance and self-reported function • CAI is when there are residual symptoms from an ankle sprain, and it has been

reported in 18-71% of children with a history of ankle sprain

- CAI has been reported to show decrease in physical activity in the adult population, but little is known about its effect on adolescents
- Rehabilitation programs are usually recommended for CAI without operations
- The effect of these programs has been evaluated in adults but not adolescents
 - Major barriers include the time requirement, space to do the exercises, and effort required to complete it
- Targeting through athletic trainers in high school settings is a possible solution
 - Not effective because ATs don't have the time or resources to personalize for patients daily
 - Patients don't receive the best level of care
- To measure the level of impairment
 - They use functional task assessment based on lab-based measures
 - These methods focus on mechanical and sensory measures
 - To address the perceptual aspect, they use clinical questionnaires
- Long term effects have not really been addressed in literature
- Multimodal interventions for CAI are effective but not practical in a high school setting
- Questionnaires focused on adolescents are used very little in current literature
- **Therefore, the purpose of our study was to compare the effects of single and multimodal interventions in adolescents with CAI on clinical measures of balance and Patient Reported Outcomes (PROs) at the point of care.**
- Single blinded randomized controlled clinical trial
- Evaluated the effects of 3 ankle rehabilitation programs
- Study was approved by Review Board of Georgia State University and patients had signed parental permission
- They calculated the minimum # of participants needed to determine real affect from previously published data
 - 6-8 participants per group (24-32 total)
 - This obtains a power of 0.80 (probability of detecting a real effect)
 - Level of 0.05 (chance of randomness)
 - Oversampled to protect against dropouts
- From 10 high schools, 55 participants were screened for eligibility (Ages 15-18 years)
 - 12 were determined ineligible leaving 43 total participants
 - Each patient reported a minimum of 5 hours of moderate activity each week
 - Inclusion and exclusion criteria were based on recs from the IAC
 - Included if they had a history of at least 1 substantial ankle sprain that required medical intervention
 - Repeated episodes of bad symptoms
 - **Cumberland Ankle Instability Tool** questionnaire scores less than or equal to 25.
 - Excluded if lower extremity injury in past 3 months
 - Acute ankle sprain in the past 6 weeks
 - Or any previous surgery in lower extremities or history of ankle

fracture/dislocation

- Patient age, height, mass, sex, limb length, and test limb were recorded
 - **Age (y)**: Average age of participants in each group, with standard deviation (SD) showing how spread out the ages were.
 - **Height (cm)**: Average height in centimeters \pm SD.
 - **Mass (kg)**: Average weight in kilograms \pm SD.
 - **Sex, males/females**: Number of males vs. female participants in each group.
 - **Test foot, right/left**: Whether the right or left foot was tested.
 - **Positive anterior drawer test**: Number of participants in each group who tested positive (indicating ankle instability).
 - **Positive talar tilt test**: Same idea, another clinical test for ankle instability.
- All patients did initial static and dynamic balance tests and completed 2 PRO questionnaires to determine any changes due to interventions for ankle function.
- The order of the tests was counterbalanced (Randomized) so no group was tested in the same sequence, avoiding bias
- One administrator scored the tests, and they were blindsided which means they didn't know the groups to avoid bias
- After baseline testing the participants were randomly organized into one of the 4 groups:
 - Resistance Band
 - Biochemical Ankle Platform System Board
 - Combination
 - Control
- The control group did not receive any rehabilitation during the 4 weeks (they could have done placebo to delete any psychological effects)
- Rehab Groups: completed the testing within 3 days after their program
- Control Group: completed the testing within 3 days of their 4-week timespan
- Static Balance Tests:
 - Time-in-Balance Test:
 - Patients stood normally
 - They were told to balance on their tet foot
 - Each trial lasted for a max of 60 seconds
 - Single practice trial for familiarization
 - Test conducted 3 times with 30 seconds of rest between trials
 - Longest trial was used for analysis
 - Test is valid and responsive to rehabilitation
 - Interclass correlation coefficient (ICC) = 0.99 which is a statistic used to measure the agreement between

multiple measurements of the same quantity or the reliability of observations within a group

- Foot Lift Test:
 - The faced forward, standing on their testing foot and hands on their hips and their eyes closed
 - Test preformed for 30 seconds
 - Looked for the number of foot lifts (number of times any part of the foot left the floor)
 - Patients were told not to remove hands from hips, open eyes, or touch the standing foot with the collateral foot but this was not recorded as an error
 - Single practice trial
 - 3 times with 30 second rest periods between trials
 - Average of the trials was taken for analysis
 - ICC = 0.99
- Dynamic Balance Tests:
 - Star Excursion Balance Test
 - Patients stood on test limb and tried to reach as far as possible in 5 reach directions (anterior, anteromedial, medial, posteromedial, and posterolateral)
 - Each reach took place over a cloth tape measure that was taped to the floor
 - Normalized to the patients' non-test limb length
 - 4 practice trials in each direction
 - 5 min rest period before the test sessions
 - Test was 3 times in each direction and average used for analysis
 - ICC = 0.81-0.93
 - Functional Performance
 - Side Hop Test:
 - Patient stood on test limb and 30 cm laterally side to side for 10 reps as fast as possible
 - Time recorded
 - Single practice trial
 - Conducted twice on test limb with 60 sec rest between trials (too short?)
 - Shortest trial was used for analysis
 - ICC = 0.99
 - Figure-8 Hop Test
 - Stood on test limb and hopped over a 5m distance in a figure 8 pattern
 - Time was recorded

- Single Practice Trial
- Conducted twice with test limb with a 60 second rest between trials
- Shortest trial was used for analysis
- ICC = 0.98
- Patient Reported Outcomes
 - Foot Ankle Ability Measure
 - Asses general self-reported levels of function in patients with musculoskeletal injuries and disorders
 - 2 subscales (Activities of Daily Life and Sports)
 - From 0% to 100% score with higher percentage meaning a better level of function
 - Valid for assessing function in adults
 - Minimal detectable change (smallest change that can be interpreted as real change)
 - Daily living: 3.9% - 4.8%
 - Sport: 7.6% - 7.9%
 - Minimal Clinically important difference
 - Daily Living: 8 points
 - Sport: 9 points
 - Cumberland Ankle Instability Tool (CAIT)
 - Assess severity of functional problems in patients with ankle instability
 - 30-point scale
 - Higher response is a better level of overall function
- Rehabilitation Interventions
- 12 rehab sessions to complete in 4 to 6 weeks with 2-3 sessions per week. Each week the difficulty of exercises increased.
 - Resistance Band Intervention:
 - Equipment: TheraBand resistance band
 - Movements Trained: Plantar flexion, dorsiflexion, inversion, eversion
 - Sets: 3 sets for 10 reps each movement
 - Patient Positioning: Seated on floor knee extended
 - Heel supported on a bolster (to lift foot off the floor)
 - Movement isolated at the ankle (no hip/knee compensation)
 - Band attachment: Double and secured to the base of a treatment table
 - Resistance calculation (From external study)
 - Calculate 70% of the resting length of the band

- Add this distance to the resting length
 - Mark this point on the floor as the stretch distance
 - During each exercise, the band was stretched to this marked distance
 - Weekly the band had a higher resistance
- Biomechanical Ankle Platform System Board Intervention
 - Setup: Patient stood near a wall allowed to use fingertips only for balance support
 - Exercise performed on single test limb
 - Task: On board, patient performed circular movements at the ankle joint
 - Clockwise and counterclockwise where direction changed every 10 seconds
 - Progression Levels: Training started at Lev. 1: smallest half dome + smallest ankle motion) and went to Lev. 5 (largest)
 - Higher levels = increased range of motion + greater difficulty
 - Training Volume: Five trials per session where each trial was 40 seconds of movement and 1 min rest between trials
 - Progression Criteria: Demonstrate smooth controlled circular rotations in both directions and transition between directions smoothly.
- Combination Intervention
 - Completed both TheraBand resistance training and BAPS Board protocols in each session
 - Counterbalanced for each session to avoid order effects
- Control intervention:
 - No rehabilitation exercises
 - Check in weekly with research team to discuss changes in ankle and report any injuries
- Data Analysis Overview
 - Preliminary Step: Correlation Analysis (All correlations were close to 1 which meant a positive correlation)
 - The study measured several outcomes within the same construct (ex. Multiple static balance tests)
 - Correlation analysis confirmed that these outcomes were related enough to be considered together as a group for multivariate analysis
 - If variables were not correlated, it wouldn't make sense to combine them because MANOVA assumes that dependent variables are related.
 - Multivariate Analysis of Variance (MANOVA)

- MANOVA is like ANOVA but for multiple dependent variables at once
- ANOVA (Analysis of Variance) compares the mean of groups to see if they are statistically different
- MANOVA does this across several related outcomes simultaneously, controlling for correlations between them.
- Four constructs: static balance, dynamic balance, functional balance, and PROs
- Each construct has multiple measures (ex different balance tests)
- MANOVA helps determine:
 - Time effect: Did participants improve from pretest to posttest?
 - Group effect: Were there differences between resistance band, BAPS, combination, or control groups?
 - Interaction effect: Did the improvement over time differ depending on the group?
- MANOVA reduces the chance of false positives that could happen if you ran separate ANOVAs on each variable without accounting for correlations.
- Univariate ANOVAs (Follow-Up Tests)
 - ANOVA looks at one dependent variable at a time
 - If MANOVA shows a significant interaction, it tells you something in the set of variables changed, but it doesn't tell you which one.
 - Follow up univariate ANOVAs are run on each variable separately to pinpoint which outcomes caused the interaction
 - For example, if the MANOVA for static balance is significant, univariate ANOVAs can tell you whether it was the single-leg stance test, the Star Excursion Balance Test, or both that drove the effect.
- Turkey Honestly Significant Difference (HST) Test
 - Post-hoc pairwise comparison test
 - Compares every group to every other group to see which specific groups differ
 - Adjusts for multiple comparisons to avoid inflating false positives
 - Suppose the univariate ANOVA shows a significant group effect on dynamic balance
 - Turkey HSD will tell you whether, for example, the combination group improved more than the control group, or if the resistance band group vs BAPS group differ significantly
- Effect Size: Hedges'g

	<ul style="list-style-type: none"> ▪ Measures the magnitude of a difference, not just whether it is statistically significant ▪ Small = 0.2, moderate = 0.5, large = 0.8 ▪ Statistical significance can be misleading if the sample size is very large or small ▪ For example, a statistically significant improvement may be very small, but a large Hedges'g means it's likely clinically significant. ○ Minimal Detectable Change (MDC) <ul style="list-style-type: none"> ▪ The smallest change in a measure that is beyond the expected measurement ▪ Calculated using the standard error of measurement and the reliability of the test (ICC) ▪ Even if a score changes from pretest to posttest, it might just be random measurement error ▪ MDC tells you the minimum change that can be confidently considered real ▪ Calculating MDC using the control group data ensures that any improvement in the experimental groups exceeds what could happen naturally or due to measurement variability ○ Statistical Significance (Alpha level) <ul style="list-style-type: none"> ▪ Chance of false positives ● Main Finding <ul style="list-style-type: none"> ○ All three intervention groups showed improvements compared to the control group ○ However, no single intervention was clearly superior ○ PROs – only time effects were significant -> everyone improved overtime but no group outperformed another ● Conclusions <ul style="list-style-type: none"> ○ All interventions worked but none clearly outperformed the others ○ Improvements were statistically significant (F/p values) and clinically meaningful in some cases (MDC/MCID surpassed) ○ For clinicians: any of these protocols can be used in a school/athletic setting because they're simple, low-equipment, and effective.
Research Question/Problem / Need	

Important Figures

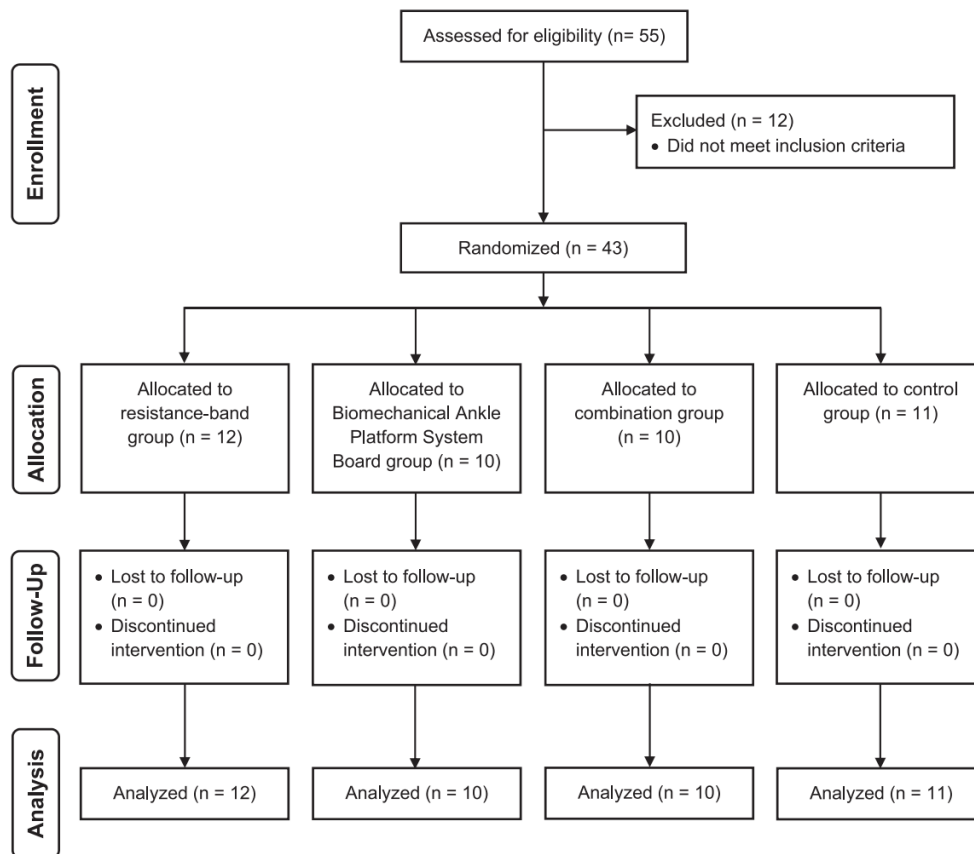


Figure 1. Consolidated Standards of Reporting Trials (CONSORT) flow diagram.

Figure 1: Flow chat of patient journey and the path of the study

Table 1. Patient Characteristics

Variable	Group			
	Resistance Band (n = 12)	Biomechanical Ankle Platform System Board ^a (n = 10)	Combination (n = 10)	Control (n = 11)
	Mean ± SD			
Age, y	16.42 ± 1.00	16.40 ± 0.97	16.20 ± 1.14	16.45 ± 1.04
Height, cm	171.24 ± 10.13	178.69 ± 9.87	170.69 ± 12.14	166.96 ± 14.20
Mass, kg	65.75 ± 11.16	77.57 ± 21.54	67.99 ± 16.49	67.17 ± 22.94
	No.			
Sex, males/females	5/7	8/2	3/7	4/7
Test foot, right/left	7/5	5/5	5/5	7/4
Positive anterior drawer test	12	10	10	11
Positive talar tilt test	12	10	10	11

^a System Spectrum Therapy Products, LLC, Adrian, MI.

Table 1: This table shows that each of the patients were similar in age, height, weight, sex distribution, test foot, and ankle instability tests. This is important because the study groups were balanced and comparable.

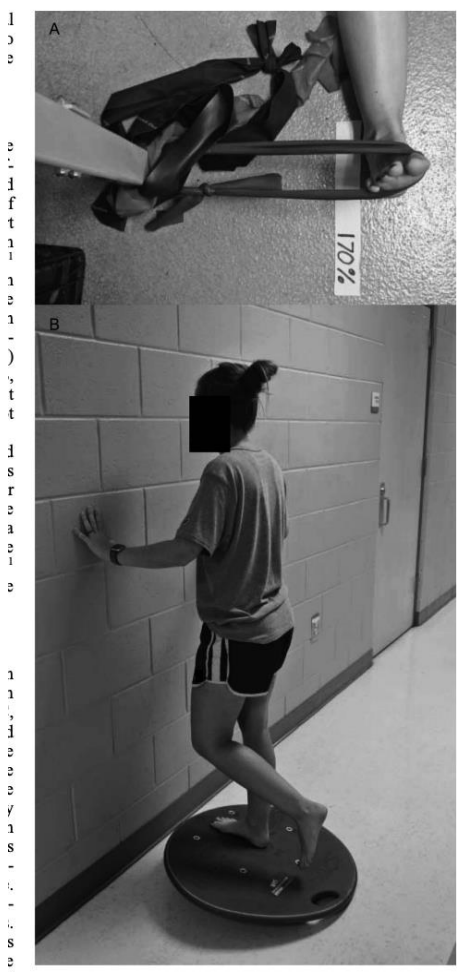


Figure 2. Participant setup. A, Resistance band. B, Biomechanical Ankle Platform System Board (Spectrum Therapy Products, LLC, Adrian, MI).

Figure 2: Pictures of both types of rehabilitation, setup and materials used.

Table 2. Dependent Variable Main Effects and Interactions

Category	Time Main Effect		Multivariate Group Main Effect		Time × Group Interaction		Variable	Time Main Effect		Univariate Group Main Effect		Time × Group Interaction	
	F	P	F	P	F	P		F _{1,39}	P	F _{3,39}	P	F _{3,39}	P
	Value	Value	Value	Value	Value	Value		Value	Value	Value	Value	Value	Value
Static balance	5.03	.01 ^a	0.87	.52	4.22	.001 ^a	Time-in-balance test	0.02	.88	0.77	.52	5.92	.002 ^a
Dynamic balance	10.15	<.001 ^a	0.98	.48	1.71	.06	Foot-lift test	9.74	.003 ^a	0.52	.67	3.44	.03 ^a
							SEBT anterior-reach direction	2.81	.10	0.76	.52	1.01	.40
							SEBT anteromedial-reach direction	14.79	<.001 ^a	0.34	.79	1.42	.25
							SEBT medial-reach direction	25.98	<.001 ^a	1.10	.36	4.74	.007 ^a
							SEBT posteromedial-reach direction	40.47	<.001 ^a	0.95	.43	3.64	.02 ^a
							SEBT posterolateral-reach direction	51.23	<.001 ^a	0.93	.44	3.35	.03 ^a
Functional performance	21.23	<.001 ^a	2.54	.03 ^a	3.58	.004 ^a	Side-hop test	18.53	<.001 ^a	1.93	.14	2.64	.06
Patient-reported outcomes	4.87	<.001 ^a	0.61	.79	1.00	.48	Figure-8 hop test	43.09	<.001 ^a	1.54	.22	4.48	.009 ^a
							NA	NA	NA	NA	NA	NA	

Abbreviations: NA, not applicable; SEBT, Star Excursion Balance Test.
^a Indicates difference ($P < .05$).

Table 2: MANOVA and Univariate ANOVA results -

- Balance, functional performance and PROs generally improved over time.
- Group differences: Most improvements weren't simply "time effects" but rather

time x group interactions meaning the rehabilitation interventions helped more than control.

- For dynamic balance, specific SEBT reach directions (medial, posteromedial, posterolateral) showed group-dependent improvements.
- For functional performance, the figure-8 hop test especially showed differences between groups
- PROs improved across everyone, regardless of intervention

Table 3. Dependent Variable Minimal Detectable Change, Mean ± SD, and Hedges g Effect Size Continued on Next Page

Variable	Minimal Detectable Change	Pretest	Posttest	Δ After 4 wk	Effect Size (95% Confidence Interval)	
					Versus Control Group ^a	Versus Combination Group ^a
Static balance						
Time-in-balance test	15.16 s					
Resistance band		29.03 ± 23.63	40.84 ± 23.80	11.81 ± 15.33	1.68 (-4.64, 8.01)	0.44 (-5.38, 6.27)
BAPS Board		29.86 ± 22.61	28.33 ± 23.61	-1.53 ± 20.07	0.73 (-6.91, 8.38)	-0.40 (-7.65, 6.85)
Combination		21.15 ± 21.12	26.56 ± 16.06	5.41 ± 12.02	1.41 (-4.59, 7.41)	
Control		33.80 ± 20.71	18.59 ± 12.20	-15.21 ± 15.63		
Foot-lift test						
Resistance band	3 errors	7.42 ± 4.41	6.42 ± 4.51	1.00 ± 3.08	0.34 (-0.82, 1.50)	-0.91 (-2.00, 0.19)
BAPS Board		7.60 ± 4.67	7.17 ± 4.89	0.43 ± 2.30	0.17 (-0.87, 1.21)	-1.37 (-2.30, -0.44)
Combination		8.93 ± 2.88	5.47 ± 2.34	3.46 ± 1.91 ^a	1.46 (0.49, 2.44)	
Control		5.64 ± 3.29	5.64 ± 2.79	0.00 ± 2.56		
Dynamic balance						
SEBT anterior-reach direction	5.33%					
Resistance band		77.57 ± 5.17	80.11 ± 5.76	2.53 ± 6.12	0.42 (-2.13, 2.97)	-0.08 (-2.48, 2.33)
BAPS Board		75.29 ± 6.18	75.62 ± 5.80	0.33 ± 3.18	0.10 (-2.09, 2.29)	-0.58 (-2.49, 1.33)
Combination		76.64 ± 7.58	79.63 ± 6.12	2.99 ± 5.28	0.52 (-2.00, 3.03)	
Control		78.38 ± 6.82	78.20 ± 6.29	-0.18 ± 6.38		
SEBT anteromedial-reach direction	3.82%					
Resistance band		79.91 ± 5.51	84.79 ± 5.18	4.88 ± 6.56 ^c	0.74 (-1.65, 3.13)	0.20 (-2.18, 2.59)
BAPS Board		79.81 ± 6.66	83.62 ± 5.66	3.81 ± 4.82	0.67 (-1.41, 2.76)	0.03 (-2.00, 2.06)
Combination		79.62 ± 8.02	83.29 ± 6.39	3.67 ± 4.42	0.67 (-1.34, 2.68)	
Control		83.72 ± 6.67	84.11 ± 6.61	0.39 ± 4.93		
SEBT medial-reach direction	5.05%					
Resistance band		81.03 ± 8.75	89.93 ± 9.59	8.90 ± 8.12 ^c	1.32 (-1.71, 4.35)	0.37 (-2.76, 3.51)
BAPS Board		81.23 ± 5.60	90.17 ± 7.93	8.94 ± 7.81 ^c	1.37 (-1.71, 4.35)	0.39 (-2.79, 3.57)
Combination		79.36 ± 8.53	85.36 ± 6.53	6.00 ± 6.65 ^c	1.06 (-1.70, 4.43)	
Control		88.81 ± 8.64	87.54 ± 8.52	-1.27 ± 6.55		
SEBT posteromedial-reach direction	6.58%					
Resistance band		82.42 ± 8.96	94.04 ± 10.33	11.62 ± 7.79 ^c	1.25 (-2.05, 4.55)	0.21 (-3.07, 3.49)
BAPS Board		85.78 ± 8.89	94.37 ± 9.89	8.59 ± 8.49 ^c	0.85 (-2.76, 4.46)	-0.15 (-3.75, 3.44)
Combination		80.15 ± 10.73	90.06 ± 10.47	9.91 ± 7.90 ^c	1.03 (-2.46, 4.52)	
Control		91.32 ± 13.10	92.45 ± 11.53	1.13 ± 8.39		
SEBT posterolateral-reach direction	7.04%					
Resistance band		74.57 ± 12.04	85.92 ± 12.45	11.35 ± 8.17 ^c	0.96 (-2.40, 4.33)	-0.23 (-3.32, 2.86)
BAPS Board		77.23 ± 13.37	84.58 ± 9.27	7.35 ± 8.91 ^c	0.47 (-3.21, 4.15)	-0.72 (-4.10, -2.66)
Combination		67.46 ± 11.45	80.59 ± 9.05	13.13 ± 6.29 ^c	1.29 (-1.88, 4.47)	
Control		78.70 ± 12.42	81.84 ± 9.11	3.14 ± 8.30		
Functional performance						
Side-hop test	0.97 s					
Resistance band		14.94 ± 5.82	10.94 ± 2.47	4.00 ± 5.09 ^c	1.05 (-0.51, 2.61)	0.26 (-1.58, 2.10)
BAPS Board		11.70 ± 4.46	8.41 ± 1.45	3.29 ± 4.01 ^c	1.13 (-0.14, 2.39)	0.13 (-1.50, 1.75)
Combination		12.43 ± 3.64	9.63 ± 1.09	2.80 ± 3.39 ^c	1.12 (0.03, 2.21)	
Control		10.84 ± 2.78	11.01 ± 3.27	-0.17 ± 1.45		
Figure-8 hop test	0.98 s					
Resistance band		14.59 ± 2.92	13.02 ± 1.85	1.57 ± 1.64 ^c	0.70 (0.11, 1.29)	-0.71 (-1.56, 0.14)
BAPS Board		13.42 ± 1.58	12.09 ± 1.61	1.33 ± 0.76 ^c	0.77 (0.33, 1.20)	-0.93 (-1.71, -0.14)
Combination		16.27 ± 3.26	13.20 ± 1.82	3.07 ± 2.42 ^c	1.30 (0.50, 2.11)	
Control		14.17 ± 2.23	13.65 ± 1.77	0.52 ± 1.20		
Patient-reported outcomes						
Foot and Ankle Ability Measure-Activities of Daily Living	10.68%					
Resistance band		87.40 ± 8.07	89.68 ± 9.24	2.28 ± 7.43	0.03 (-3.92, 3.99)	-0.56 (-3.21, 2.09)
BAPS Board		89.40 ± 8.39	92.86 ± 9.10	3.46 ± 6.58	0.15 (-3.96, 4.26)	-0.42 (-2.92, 2.08)
Combination		85.36 ± 11.42	91.31 ± 8.80	5.95 ± 4.66	0.42 (-3.45, 4.30)	
Control		89.07 ± 10.14	91.02 ± 9.38	1.95 ± 11.67		
Foot and Ankle Ability Measure-Sport	9.51%					
Resistance band		69.01 ± 11.73	81.25 ± 12.29	12.24 ± 13.62 ^c	0.43 (-5.25, 6.12)	0.12 (-5.31, 5.55)
BAPS Board		77.50 ± 13.24	84.38 ± 14.95	6.88 ± 10.91	0.07 (-5.39, 5.52)	-0.31 (-5.37, 4.75)
Combination		74.06 ± 14.44	84.69 ± 17.21	10.63 ± 12.17 ^c	0.34 (-5.34, 6.02)	
Control		71.02 ± 15.51	76.99 ± 19.93	5.97 ± 14.21		

Table 3: The combination group consistently showed the greatest improvements, often exceeding the MDC thresholds, meaning the changes were real and clinically meaningful. The resistance band group showed improvements in balance and function but come were just below MDC. The BAPS group showed smaller or inconsistent improvements compared to the combination group. The control group had little to no improvement.

VOCAB:
(w/definition)

Chronic Ankle Instability (CAI): A long-term condition following ankle sprains, marked by recurring instability, weakness, and episodes of the ankle “giving away”

	<p>Minimal Detectable Change (MDC): The smallest change in a measurement that exceeds normal variation of error, meaning the change is “real”.</p> <p>Minimal Clinically Important Difference (MCID): The smallest improvement in a score that patients perceive as beneficial and that would justify a change in care.</p> <p>Multivariate Analysis of Variance (MANOVA): A statistical test used to assess differences between groups on multiple dependent variables at once, controlling for correlations among them.</p> <p>Patient-Reported Outcomes (PROs): Assessments completed directly by patients to report their own perception of health, function, or quality of life, without clinician interpretation.</p>
<p>Cited references to follow up on</p>	<ol style="list-style-type: none"> 1. Hertel, J. (2002). Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. <i>Journal of Athletic Training</i>, 37(4), 364–375. 2. Haley, S. M., Fragala-Pinkham, M. A. (2006). Interpreting change scores of tests and measures used in physical therapy. <i>Physical Therapy</i>, 86(5), 735–743. https://doi.org/10.1093/ptj/86.5.735
<p>Follow up Questions</p>	<ol style="list-style-type: none"> 1. Since this study found no clear benefit to combining resistance-band and balance board interventions, how might longer intervention duration or different progression strategies influence outcomes? 2. What are the potential differences in how adolescents versus adults respond to CAI rehabilitation, and how could this shape clinical recommendations for younger athletes?

Article #4 Notes: Effects of an exoskeleton-assisted gait training on post-stroke lower limb muscle coordination

Article notes should be on separate sheets

Source Title	Effects of an exoskeleton-assisted gait training on post-stroke lower limb muscle coordination
Source citation (APA Format)	Zhu, F., Kern, M., Fowkes, E., Afzal, T., Contreras-Vidal, J.-L., Francisco, G. E., & Chang, S.-H. (2021). Effects of an exoskeleton-assisted gait training on post-stroke lower-limb muscle coordination. <i>Journal of Neural Engineering</i> , 18(4). https://doi.org/10.1088/1741-2552/abf0d5
Original URL	https://iopscience.iop.org/article/10.1088/1741-2552/abf0d5
Source type	Journal Article
Keywords	Found through WPI professor pages
#Tags	
Summary of key points + notes (include methodology)	<p>Summary of Key Points:</p> <p>This study investigated how powered exoskeletons affect neuromuscular coordination in stroke patients, addressing a major gap in existing research. Eleven healthy and ten post stroke individuals participated in gait assessments, with five stroke subjects completing 10-15 sessions of Ekso assisted gait training. Results showed that while training did not significantly improve walking performance, endurance, or coordination complexity, immediate exoskeletons modulated muscle activation patterns toward normal gait, improving symmetry and foot clearance but also introducing unnatural activations due to mechanical constraints. These effects were functional. Not speed-related and highlights the exoskeleton's ability to influence motor coordination rather than simply aid movement. The findings suggest that exoskeletons may benefit stroke patients with severe gait asymmetry or foot drop, but users with weak leg muscles may experience discomfort. Overall, the study emphasizes that long-term, high-intensity training and improved exoskeleton design, lighter, less restrictive, and more adaptive, are needed to translate immediate motor coordination changes into lasting functional recovery.</p>

Article Notes:

- Powered exoskeletons (braces) have been used to help stroke patients with gait impairment but there is no research on effects on neuromuscular coordination.
- 11 able bodied patients, and 10 stroke patients in a single visit treadmill walking assessment (assessed motion and lower limb muscle activities)
- This is how they move through space over time **spatiotemporal**, kinematics, and **muscle synergy patterns**
- Using this data, they figured out normal gait pattern and post-stroke motor deficits
- 5 stroke subjects received exoskeleton assisted gait trainings
 - Walking tests for pre-intervention, and post intervention (Without and with)
- Post Stroke Gait Impairment
 - Stroke is one of the leading causes of death
 - Major cause of serious disabilities
 - Hemiplegia: reduced gait performance
 - Recovery of this is a major focus of stroke rehab
- Exoskeleton Assisted Rehabilitation
 - Conventional methods are very labor intensive
 - Therapists manually guiding the affected limb
 - Robot assisted rehab is more accurate and precise
- Muscle synergy during normal and post-stroke gait
 - Walking is coordinating muscles and processing info to refine that motion
 - Specific muscle groups are responsible for specific types of motion (4 modules from a previous study)
 - Post-stroke subjects had fewer modules cause their groups were merged
 - This leads to less precise movement
- Muscle Synergy during exoskeleton assisted walking
 - Basically, the exoskeleton is to reduce workload of the impaired limbs and reinforce desired normal limb trajectories
 - Studies show exoskeletons improve muscular performance during walking
 - Exoskeletons can change muscle synergy patterns in healthy and spinal cord injury subjects
 - GAP: No published studies have yet examined this effect in stroke populations, particularly in longitudinal training.
- Hypothesis:
 - Stroke results in lowered neuromuscular coordination complexity
 - Assistance from a powered exoskeleton will change stroke user's motor coordination patter towards "normal"
 - Longitudinal intervention will have minor effects on stroke subject's locomotion performance
- **Participants:** 11 healthy adults and 10 chronic post-stroke individuals

(Stage 1); 5 stroke participants continued into longitudinal exoskeleton-assisted training.

- **Inclusion criteria (stroke group):** ≥ 18 years old, ≥ 6 months post-stroke, cognitively intact, able to consent/stand/sit-to-stand, weight < 220 lbs, adequate RoM, intact skin, proper exoskeleton fit.
- **Exclusion criteria:** Other neurological disorders, unhealed fractures, severe spasticity (>3 MAS), major comorbidities (cardiac, pulmonary, circulatory), active DVT, or colostomy
- **Ethics:** Approved by UTHealth CPHS; written informed consent obtained
- **Data Notes:** One subject (SS10) did not complete screening; one dataset (AS11) excluded due to noise; BBS measured pre/post for stroke exoskeleton group.
- **Device:** Ekso 1.1 (Ekso Bionics, Richmond, CA), a lightweight lower limb exoskeleton.
- **Design:** Powered actuators at bilateral hip and knee joints; provides unilateral/bilateral torque in sagittal plane; restricts motion in coronal/transverse planes.
- **Features:** integrated ankle-foot orthosis (AFO) to prevent foot drip.
- **Control modes:** Programmable for either adaptive assistance (Adjusts to user performance) or fixed assistance (capped at set maximum power)
- Stage One (Baseline Treadmill Walking)
 - Subjects walked 3-5 min on a Biodex Gait Trainer at self-selected comfortable speed
 - Safety ensured with a body weight suspension harness (no lift applied)
 - Stroke participants walked without orthoses (AFO)
 - Lower limb EMG and motion data collected for muscular and kinematic performance
- Stage Two (Intervention Exoskeleton Training)
 - Stroke subjects received 10-15 sessions of Ekso assisted overground walking (up to 50 min each) over 3-4 weeks.
 - Training guided by physical therapist; robot parameters (mode, assistance level, gait initiation) adjusted to maximize challenge while encouraging normalized gait.
 - Pre/post assessments included 10MWT, TUG, and 6MWT to measure walking speed endurance
 - Energy expenditure (EE) measured breath-by-breath with CosMed K4b2 analyzer
 - EMG and motion data collected during both treadmill and overground assessments for muscular and kinematic evaluation
- **EMG recording:** Bilateral surface EMG collected from 8 muscles (TA, SOL, MG, VM, RF, BFL, SEM, GM) at 1 kHz using Motion Lab Systems
- **Motion capture:** 8 body segments and 18 bony landmarks tracked with Optotrak Certus system at 100 Hz
- **Synchronization:** Amplified EMG whereinto Optrak control unit and synchronized with motion data via FirstPrinciple software

- **Pre-Processing:** Raw motion and EMG data processed in Visual3D v6 to reconstruct 3D walking model and compute gait kinematics/spatiotemporal parameters
- **Post Processing:** Results exported in ASCII and analyzed further in Matlab R2017b
- **Kinematics:** Motion data processed in Visual3D to reconstruct 3D walking model; hip, knee, and ankle angles calculated; gait cycles segmented using heel/toe positions; data low-pass filtered (4 Hz Butterworth)
- **EMG Processing:** Raw EMG band-pass filtered (20-250 Hz), rectified smoothed with 4 Hz low-pass filter; normalized to channel max to create linear envelope.
- **Gait Cycle & Phases:** Heel strike and toe off detected via Zeni algorithm, invalid gait cycles removed; valid cycles segmented into six phases (double supports, single supports, swing phases).
- **Averaging Features:** Kinematics & EMG LE time-normalized to 100% gait cycle; averaged across good strides (Stage 1) or kept as individual strides for statistical analysis (Stage 2)
- **Muscle Synergy Extraction:** Synergies defined by weight vectors (muscle contributions) + time activation profiles; extracted via non-negative matrix factorization (NNMF); two-step process (multiplicative update + alternating least squares) used for stability
- **Module Number Determination:** Variability accounted for (VAF) >90% criterion applied across 15 conditions (whole gait, each muscle, each phase); module number set per subject, then averaged (AveSynNum) for group-level analysis.
- **Classification:** Extracted modules clustered with K-means (K = AveSynNum); classified by similarity (Pearson correlation) to cluster centroids to align modules across subjects/legs.
- Comparisons:
 - EET (Exoskeleton Effect of Training): Pre vs. Post intervention
 - EEW (Exoskeleton Effect of Wearing): Walking without (WO) vs. With (WT) exoskeleton.
- Synergy analysis:
 - Weight comparison (W): Similarity assessed with Pearson correlation.
 - Activation profiles (SynAct): Compared by firing amplitude at each time frame
- Muscle/channel analysis: Active individual muscle channels compared between conditions
- Statistical Tests:
 - Normal data: Independent Student's t-test ($p < 0.05$)
 - Non-normal data: Wilcoxon rank sum test ($p < 0.05$)
 - Normality check: Kolmogorov-Smirnov test
 - Multiple strides: Bonferroni correction applied (N=9 strides/condition)
- Other measures: Same tests applied to gait spatiotemporal parameters,

locomotion assessments, and EE

- Healthy walking can be reconstructed with about 4 muscle synergy modules (group mean ~ 4.45)
- These 4 modules explain $>90\%$ of muscle activity (high VAF)
- Example subject: 4 modules captured 96.5% of gait variability, confirming modular control of walking.
- Across all 20 legs, 4 consistent synergy modules were identified, each tied to a distinct gait phase and function
- Module 1 (M1): Plantar flexors (SOL, MG) -> Active in mid-stance, provides support, propulsion, swing initiation.
- Module 2 (M2): Knee extensors (VM, RF) -> Active in early stance & late stance supports weight acceptance & swing initiation
- Module 3 (M3): Knee flexors (BFL, SEM) -> Active in early stance & late swing, helps leg declaration.
- Module 4 (M4): Ankle dorsiflexor (TA) + hip abductor (GM) -> Active in early stance & early swing, aids weight shift & foot clearance
- Despite small individual differences, the group average 4-module pattern matches well with prior studies.
- Stroke subjects showed impaired gait: significantly slower walking speed, shorter step length, lower foot clearance, and slightly higher stance-to-swing ratio (asymmetry)
- Paretic side deficits: reduced stance phase, lower clearance -> led to toe drag, subjects compensated with hip hiking and circular leg swing
- Joint RoM: Generally reduced in stroke subjects, especially on the paretic side; impairments linked to altered neuromuscular coordination from neural injury.
- Stroke subjects required fewer muscle synergy modules to account for 90% of lower extremity muscle activity compared to able-bodied individuals, indicating reduced movement complexity.
- Non-paretic legs needed ~ 3.8 modules and paretic legs ~ 3.1 versus ~ 4.45 modules in controls
- The paretic leg's variability plateaued at three modules, showing that fewer independent modules were sufficient for walking but contributed to poorer locomotion performance.
- Non paretic legs of stroke subjects largely retained the typical four module pattern seen in able bodied individuals, though module distinctions and muscle weights were slightly weaker
- Paretic legs showed pronounced changes: the first module merged multiple muscles (calf and quadriceps), reducing the ability to perform sequential gait tasks leading to a "whole foot flat landing" pattern instead of normal heel to toe walking.
- These alterations in module organization caused reduced locomotion performance, increased gait symmetry, compromised balance, and limited joint RoM.
- Stroke subjects completed an average of 12.6 ± 1.95 Esko-assisted gait training sessions over $\sim 25.6 \pm 12.1$ days, with training rates above 0.5

sessions/day for most participants.

- Some subjects (ES03 and ES05) had lower training rates due to health or scheduling issues
- Post-intervention gait assessments were conducted on average 4.4 +- 3.4 days after training minimizing potential loss of training effects.
- The 15-session Ekso assisted gait training did not significantly improve locomotion performance in stroke subjects; measures like walking speed, step length, foot clearance, and stance to swing ratio remained worse than able bodied controls
- Functional mobility tests (TUG, 10MWT, 6MWT) showed no significant improvement pre vs post training without the exoskeleton though using the exoskeleton (PostWT) reduced performance due to device restrictions
- Exoskeleton training did not significantly affect metabolic energy expenditure as no changes in EE rates were observed across pre and post intervention tests
- The number of muscle synergy modules needed to reconstruct walking in stroke subjects remained largely unchanged after 15-session Ekso assisted training and with exoskeleton assistance, indicating no significant improvement in overall neuromuscular coordination complexity.
- Some minor changes in module number were observed (non-paretic side increased with Ekso, reduced during overground walking) but these did not significantly affect reconstruction quality compared to pre intervention or able-bodied controls.
- Although overall complexity did not improve, fine-tuning within existing modules could still reflect subtle adaptations from longitudinal training or exoskeleton assistance.
- After 10-15 sessions of Ekso assisted gait training, muscle synergy patterns were largely preserved between pre and post intervention conditions for both treadmill and overground walking
- Only minor differences were observed: slightly weaker activation of module 1 on the paretic leg during mid-stance, and small changes in hamstring recruitment and early stance activation on the non-paretic leg.
- These results indicate that training did not significantly alter neuromuscular coordination patterns during steady-speed walking in stroke subjects
- Unlike training effects (EET), direct walking with Ekso (EEW) significantly altered muscle synergy patterns, mainly through changes in activation timing.
- On the non-paretic side, Ekso corrected delayed plantar flexor activation (closer to normal), but also caused deviations such as reduced early-stance knee extensor use, abnormal mid-swing activation, and wider hamstring activity due to restrictions
- On paretic side, Ekso had several positive effects: it promoted partial separation of merged plantar flexor/knee extensor modules, corrected abnormal wide hamstring activation linked to foot drop, and normalized excessive dorsiflexor effort at toe-off

- However, Ekso also introduced a negative effect: excessive knee extensor activation during mid-swing, as the robot's enforced range of motion exceeded what stroke subjects could comfortably perform.
- The observed module merging in stroke subjects is due to neural injury related impairment, not age or slower gait speed, since muscle synergy composition remains stable across walking speeds.
- When walking with the Ekso, subjects' gait speed decreased but the muscle synergy changes were functional effects of the exoskeleton, not just speed related variations, most alterations involved activation pattern changes rather than simple timing shifts.
- These findings confirm that Ekso assistance actively modulates neuromuscular coordination rather than merely reflecting slower walking dynamics.
- 10-15 sessions of exoskeleton assisted gait training were insufficient to produce significant improvements in walking performance, endurance, or gait symmetry in stroke subjects
- Possible reasons included too few sessions, low training intensity, and the fact that most participants were chronic stroke patients long past the optimal recovery window for neuroplastic changes
- Limited session duration (≤ 50 minutes), frequent breaks due to fatigue, and low total step counts likely prevented sufficient reinforcement of the new symmetrical gait pattern.
- The Ekso exoskeleton immediately altered stroke subjects' motor coordination showing both beneficial and adverse effects.
- Positive: Improved gait symmetry by separating merged muscle modules, reducing abnormal activations, and enhancing foot clearance through coordinated hip, knee, and footplate assistance.
- Negative: Its mechanical constraints caused unnatural muscle activations as users resisted excessive assistance, potentially reinforcing improper movement patterns.
- The Ekso exoskeleton may benefit acute or chronic stroke patients with severe gait asymmetry, foot drop, or limited joint RoM as it helps restore more normal muscle coordination through assisted movement
- However, those with weak upper-leg muscles may experience discomfort or abnormal activation due to excessive robotic assistance
- While the device can immediately adjust motor coordination it is still unclear if these changes translate to lasting functional improvement without long-term, intensive training.
- Future designs should focus on being lighter and less restrictive to better identify who benefits most from extended use.
- The Ekso exoskeleton shows promise for improving stroke patients motor coordination but can also disrupt natural gait due to added sensory input and abrupt actuator assistance
- Issues: Tight straps and rigid guidance may overwhelm users with unnatural feedback while the sudden activation of assistance during gait initiation can disturb smooth leg movement—especially in fatigued or

- unfamiliar users.
- Design improvements:
 - Make the device lighter to reduce physical and sensory strain.
 - Develop a smoother, more intuitive gait initiation system that detects walking intent with less effort
 - Implement gradual, adaptive assistance that eases in and out naturally to better support fluid realistic motion.

Research Question/Problem/ Need

How does powered exoskeleton-assisted walking affect neuromuscular coordination in stroke patients, and can it help restore more normal gait patterns compared to unassisted walking?

Important Figures

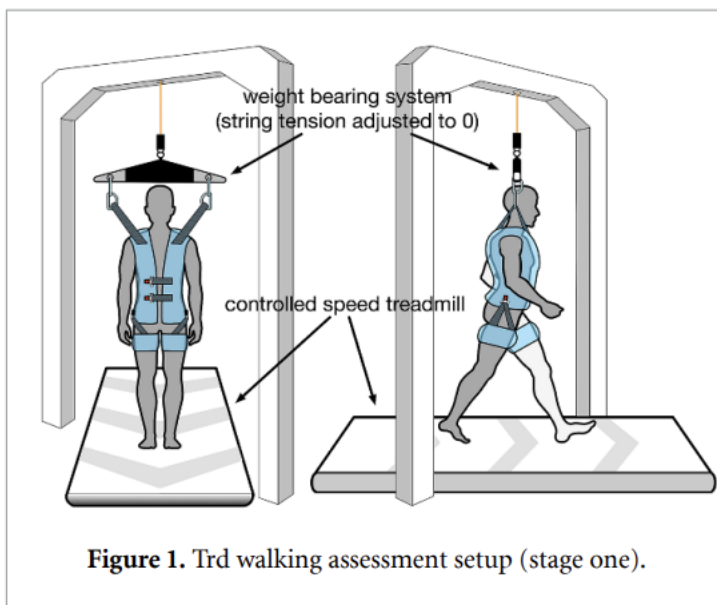


Figure 1: Depiction of Stage one testing

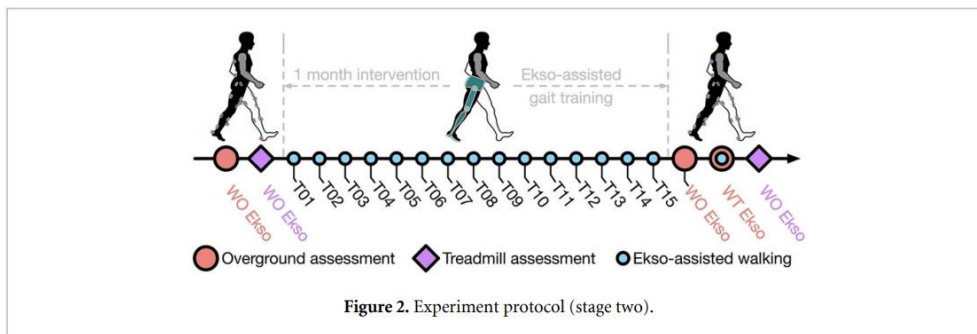


Figure 2: Shows the pre-assessments, the walking training, and post-assessments in a timeline formal

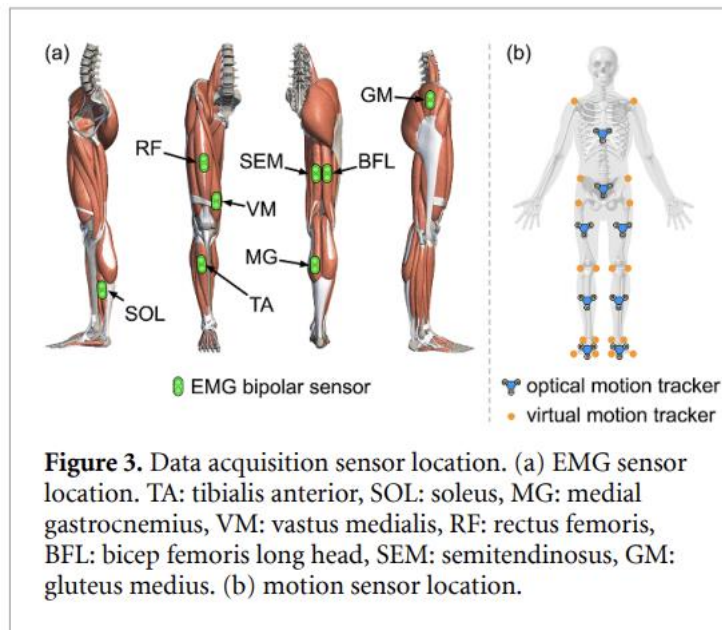


Figure 3: Shows where the sensors were located on the legs, specifies muscle groups.

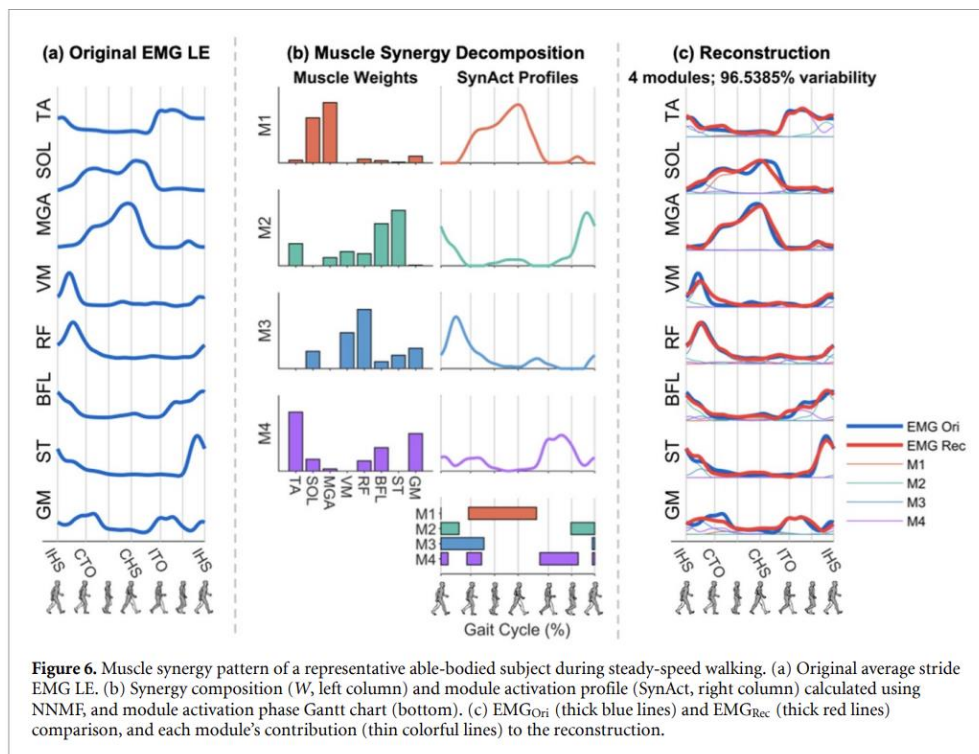


Figure 6: Divided into panels - (a) original EMG data, (b) the composition and activation profiles of extracted synergy modules (weights, time course, Gantt chart for activation timing), and (c) a comparison of reconstructed versus original EMG signals. Demonstrates how well four modules can

capture real muscle activation patterns.

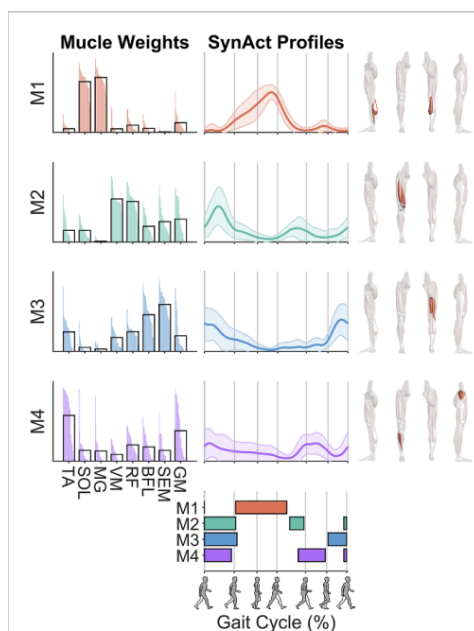


Figure 7. Muscle synergy pattern of the able-bodied subjects during steady-speed walking. The left column shows the muscle weight composition of each module. Each thin bar presents average stride performance from one leg. The black boxes denote the group average across 20 legs. The amplitude of bars represents the contribution intensity of that muscle to the module. The shaded plots in the middle column show the synergy module activation profiles. The thick lines present the group average across 20 legs and the translucent ribbons show the standard deviation range. The Gantt chart below the shaded plots demonstrates the activation phase of each module. 'Activation phase' is defined as the periods when the amplitude of the average module activation profile is above its mean across the entire gait cycle. The right column shows the recruited muscles for corresponding modules.

Figure 7: Summarizes the average muscle weight composition, activation timing, and involved muscles for each synergy module across all able-bodied legs. Provides insight into the distinct roles of each muscle synergy throughout the gait cycle—helpful for comparison to stroke-affected patterns.

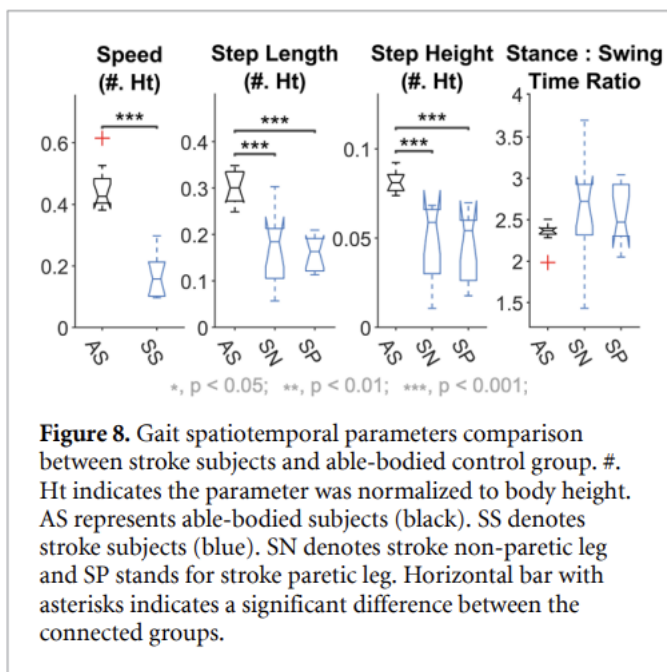


Figure 8: Bar or box plots comparing key kinematic parameters (walking speed, step length, foot clearance, height, stance-to-swing ratio) between able-bodied controls and stroke participants (and between paretic and non-paretic legs)

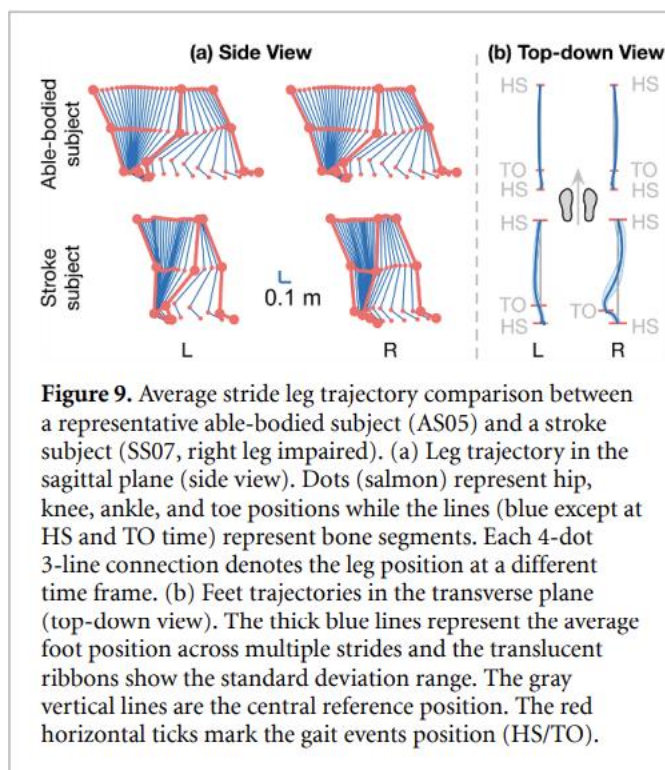


Figure 9: Overlays represent sagittal plane trajectories for both groups. The

figure visualizes how stroke changes gait with shorter stride, reduced clearance, and compensatory movement, such as hip hoking for the paretic limb.

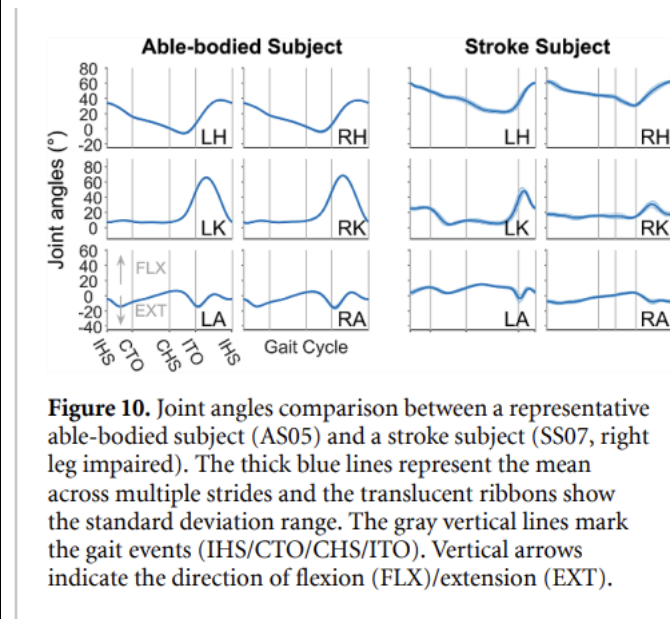


Figure 10: Plots joint angles (hip, knee, ankle) as a function of the gait cycle for healthy participant and stroke survivor, showing reduced RoM and altered timing, especially on the paretic side.

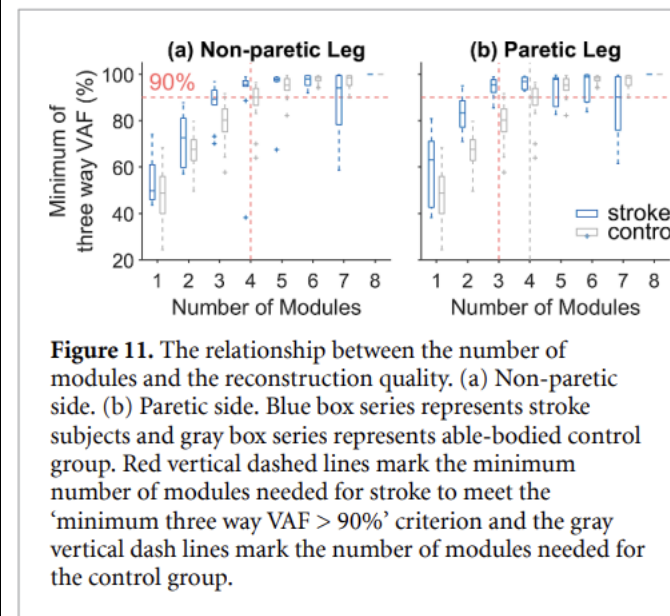


Figure 11: Boxplots or line graphs illustrating how many muscle synergies are required to explain the same amount of EMG variance in stroke versus control groups, demonstrating reduced coordination complexity on the paretic side.

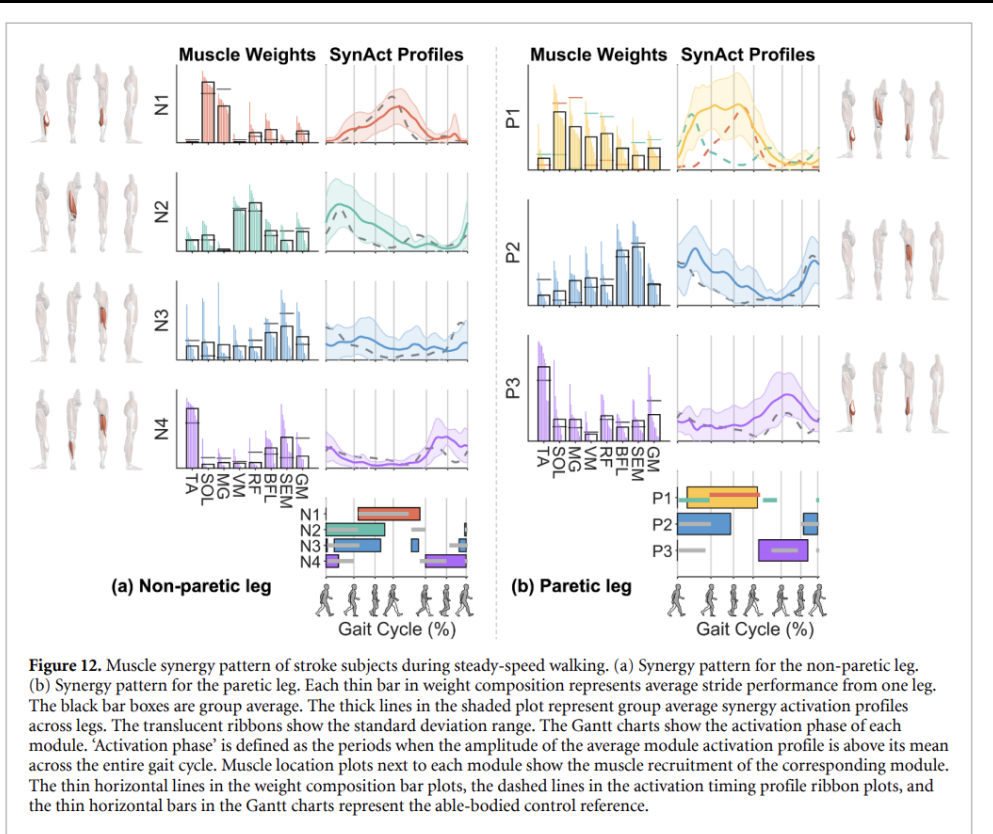


Figure 12: Bar plots and activation profiles for each extracted synergy module for both non-paretic and paretic limbs in the stroke group, highlighting the blending (or merging) of modules and reduced specificity on the paretic side compared to health controls.

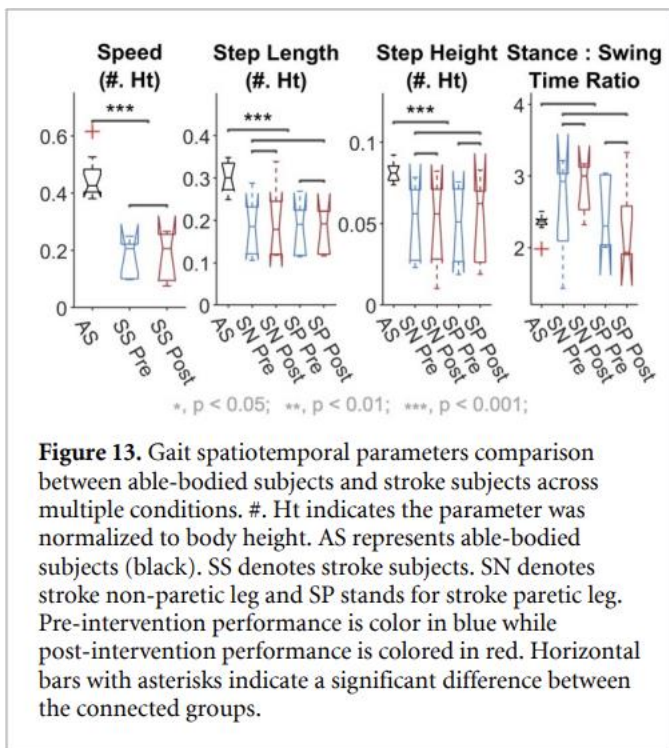


Figure 13: Plots of normalized gait parameters (speed, step length, clearance, stance/swing ratio) before and after exoskeleton-training for both legs compared to controls, revealing training effects (or lack thereof).

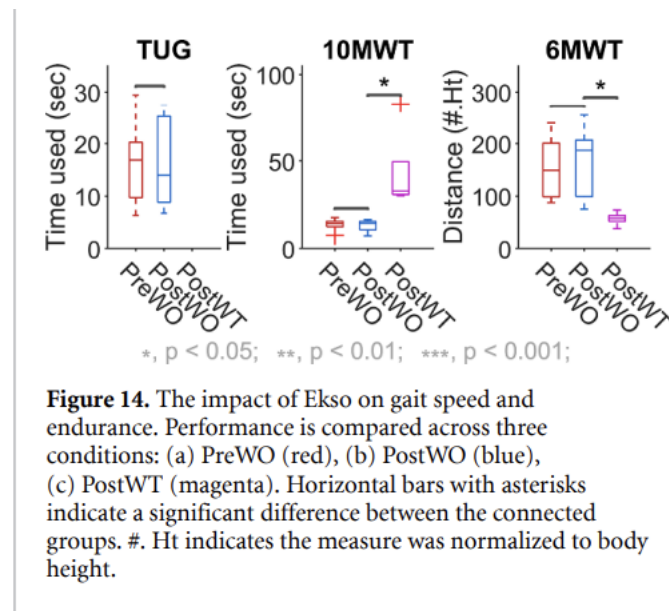


Figure 14: Compares standard function test performances across pre-training, post-training, and during exoskeleton walking illustrating differences in gait speed and endurance across conditions.

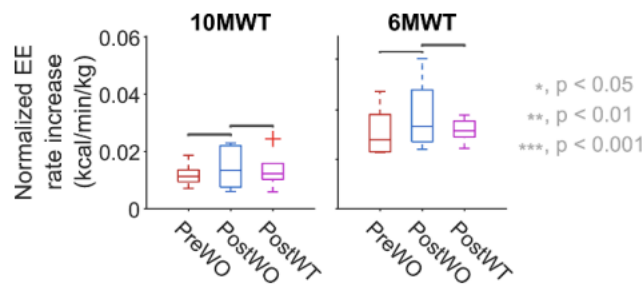


Figure 15. The impact of Ekso on EE rate. Performance is compared across three conditions: (a) PreWO (red), (b) PostWO (blue), and (c) PostWT (magenta). Horizontal bar with asterisks indicates a significant difference between the connected groups.

Figure 15: Shows energy expenditure rates (normalized for body weight) in different walking conditions to assess whether exoskeleton use/training reduces or increases the energetic cost for stroke survivors.

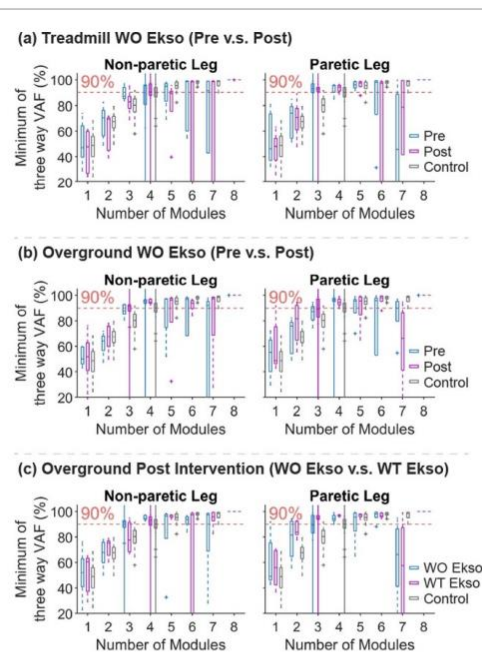


Figure 16. The relationship between the number of modules and the reconstruction quality under different conditions. (a) Trd walking (without Ekso) comparison between pre-intervention and post-intervention. (b) Ovgd walking (without Ekso) comparison between pre-intervention and post-intervention. (c) Post-intervention Ovgd walking comparison between without Ekso and with Ekso. Blue box series represents comparison group A while the magenta box series represents the comparison group B. The gray box series represents the able-bodied control group reference. Vertical lines mark the minimum number of modules needed for the color-matching series to meet the 'minimum three way VAF > 90%' criterion.

Figure 16: Similar plots to Figure 5/1 but highlighting changes in

	coordination complexity before/after training and when walking with/without the exoskeleton.
VOCAB: (w/definition)	<p>Spatiotemporal: Related to space and time (in this context, how the subjects move in space over time)</p> <p>Muscle Synergy Patterns: the coordinated activation patterns of multiple muscles working together to produce a desired movement</p> <p>Hemiparetic: Referring to weakness on one side of the body, often resulting from a stroke</p> <p>Locomotion: The ability to move from one place to another, usually referring to walking or running.</p>
Cited references to follow up on	<ol style="list-style-type: none"> 1. Werner C, Von Frankenberg S, Treig T, Konrad M and Hesse S 2002 Treadmill training with partial body weight support and an electromechanical gait trainer for restoration of gait in subacute stroke patients <i>Stroke</i> 33 2895–901 2. Kao P-C, Srivastava S, Agrawal S K and Scholz J P 2013 Effect of robotic performance-based error-augmentation versus error-reduction training on the gait of healthy individuals <i>Gait Posture</i> 37 113–20 3. Winter D A and Yack H J 1987 EMG profiles during normal human walking: stride-to-stride and inter-subject variability <i>Electroencephalogr. Clin. Neurophysiol.</i> 67 402–11
Follow up Questions	<p>Would a higher number of exoskeleton-assisted gait training sessions over a longer period lead to significant improvement in stroke patients' locomotion performance and neuromuscular coordination?</p> <p>How would changes in exoskeleton design, such as lighter weight, more adaptive assistance, or smoother gait initiation affect the balance between positive and negative impacts on muscle synergy patterns?</p> <p>Which subgroups of stroke patients would benefit most from exoskeleton-assisted rehab, and how could patient specific settings improve outcomes?</p>

Article #5 Notes: Deep Learning Reinvents the Hearing Aid

Article notes should be on separate sheets

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Source Title	Deep learning reinvents the hearing aid
Source citation (APA Format)	Wang, D. (2017). Deep learning reinvents the hearing aid. <i>IEEE Spectrum</i> , 54(3), 32–37. https://doi.org/10.1109/MSPEC.2017.7864754
Original URL	https://ieeexplore.ieee.org/document/7864754
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	The core challenge addressed by research is the “cocktail party problem,” which has long stymied hearing aid manufacturers because the devices cannot distinguish a single voice from the background noise, resulting in an “incoherent din” that often makes conversation impossible. To overcome this, researchers applied machine learning based on deep neural networks (DNNs) to create a digital filter that can isolate speech from noise and automatically adjust volumes. The methodology centers on supervised learning,

where the DNN is trained using the ideal binary mask (IBM), a perfect filter that acts as the “answer sheet”. This mask labels segmented sound elements called time frequency units as 1(speech dominant) or 0(noise dominant). The network analyzes 85 extracted features to classify these units and separate the target speech from the auditory scene. The results demonstrated a profound success: hearing-impaired subjects listening to babble noise saw their word comprehension dramatically increase from only 29% to 84% after processing. Remarkably, assisted hearing-impaired listeners outperformed people with normal hearing by nearly 20% in babble and 15% in steady noise, bringing the program the closest to solving the cocktail party problem to date. Ultimately the goal is to embed this trained program, which can now handle compleatly new noises, directly into hearing aids to restore or even exceed normal hearing comprehension.

Research Question/Problem / Need

Produce a better experience for hearing aid wearers by using machine learning based on deep neural networks (DNNs) to develop a digital filter that can isolate target speech from background noise and automatically adjust the volumes of each separately.

Important Figures

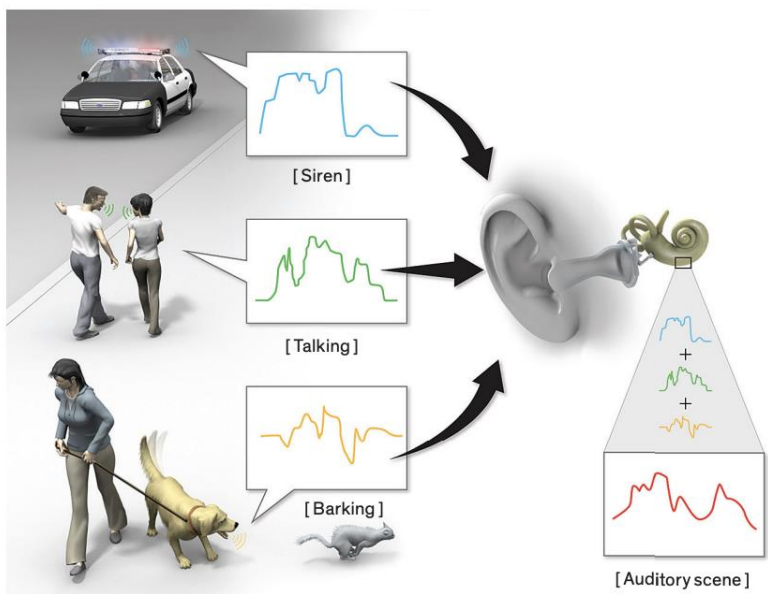


Figure 1: How the sounds are distinguished.

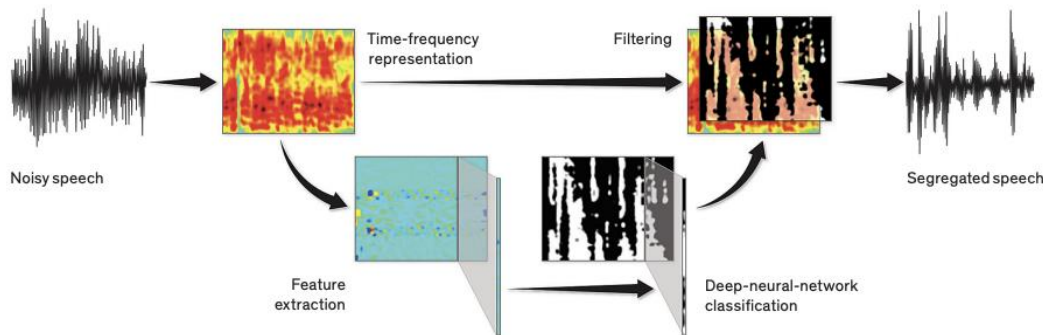


Figure 2: Flow Chart on the process to separate the speech from the background noise.



Figure 3: Different hearing devices over the years

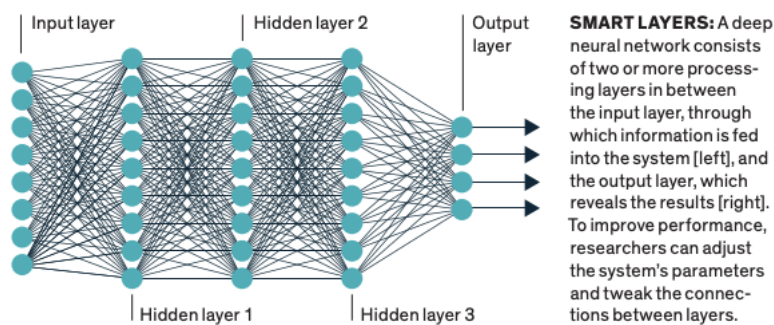


Figure 4: Diagram of the Deep Neural Network and each Hidden Layer

**VOCAB:
(w/definition)**

Deep Neural Networks (DNNs): Software systems, roughly modeled on the brain, that are constructed of simple elements to achieve complex processing and are defined as having at least two “hidden” processing layers.

Ideal Binary Mask (IBM): Filter labels segmented sound elements as 1 (if target speech is louder than noise) or 0 (if the target sound is softer), serving as the “answer sheet” to guide the supervised training of the neural network.

	<p>Time-Frequency Units: These are segments of sound that designate a particular brief interval within a specific frequency band, which the machine-learning program analyzes and classifies.</p> <p>Auditory Scene: This term refers to the collection of multiple distinct sound streams that occur at the same time, such as a friend speaking over the background roar of a hockey game.</p>
<p>Cited references to follow up on</p>	<p>No references, but here are some papers where this article was cited:</p> <ol style="list-style-type: none"> 1. Asaduzzaman, A., Deb, A., Biswas, A., Roy, R., Islam, A., & Shahnaz, C. (2024). WnD-UNET: A waveform and discrete wavelet coefficient-based 1D deep learning model for single-channel noisy speech enhancement. <i>2024 27th International Conference on Computer and Information Technology (ICCIT)</i>, 3554–3559. 2. Chao, R., Cheng, W.-H., La Quatra, M., Siniscalchi, S. M., Yang, C.-H. H., Fu, S.-W., & Tsao, Y. (2024). An investigation of incorporating Mamba for speech enhancement. <i>2024 IEEE Spoken Language Technology Workshop (SLT)</i>, 302–308.
<p>Follow up Questions</p>	<ol style="list-style-type: none"> 1. How accurately can the retrained system handle complex real-world reverberation (echoes) and noise mixtures which were omitted from initial samples? 2. What are the current computational and power consumption challenges associated with embedding the sophisticated deep neural network directly into a small, real-time hearing aid device? 3. What specific mechanisms or features derived from the 85 attributes used in the DNN are believed to be responsible for the observed super-normal hearing ability demonstrated by assisted users?

Article #6 Notes: Development of hearing technology with Personalized Safe Listening Features

Article notes should be on separate sheets

Source Title	Development of hearing technology with Personalized Safe Listening features
Source citation (APA Format)	Gupta, S., Xu, X., Liu, H., Zhang, J., Bas, J. N., & Kelly, S. K. (2020, February 13). Development of hearing technology with personalized safe listening features. <i>2020 IEEE Conference Publication</i> . IEEE. https://ieeexplore.ieee.org/document/8996137
Original URL	https://ieeexplore.ieee.org/document/8996137
Source type	Journal Article

<p>Keywords</p>									
<p>#Tags</p>									
<p>Summary of key points + notes (include methodology)</p>	<p>This article introduces the Hearing Health mobile app, designed to prevent Noise-Induced Hearing Loss (NIHL) by monitoring users’ sound exposure and promoting safe listening behaviors. The app integrates U.S. and WHO-ITU safe listening standards to calculate daily and weekly noise doses using A-weighted sound pressure levels (dBA). It collects data through smartphone microphones or Bluetooth-connected Personal Sound Amplification Products (PSAPs), provides real-time alerts and personalized recommendations, and educates users about hearing health. The methodology combines quantitative exposure calculations with user centered design, incorporating feedback from diverse groups (young adults, adults, and military users) to ensure accessibility and personalization. Aligned with WHO’s m-health and digital development principles, the app emphasizes privacy, scalability, and engagement, aiming to serve as both a preventative health tool and educational resource for improving hearing awareness across global populations.</p>								
<p>Research Question/Problem/Need</p>	<p>How can a mobile application integrate global and U.S. safe listening standards to monitor, assess, and modify users’ daily sound exposure in real-time, thereby preventing Noise-Induced Hearing Loss (NIHL) and promoting safer listening behaviors through personalized digital health interventions?</p>								
<p>Important Figures</p>	<p>Table 1 – US and UN safe listening standards [5-7, 9-13]</p> <table border="1" data-bbox="418 1062 1008 1730"> <thead> <tr> <th data-bbox="418 1062 578 1163">Exposure type</th> <th data-bbox="578 1062 1008 1163">Standard</th> </tr> </thead> <tbody> <tr> <td data-bbox="418 1163 578 1352">Recreational (audio device)</td> <td data-bbox="578 1163 1008 1352"> <p>WHO-ITU (H.870)</p> <p>Adults: 80 dBA for 40 hours a week</p> <p>Children: 75 dBA for 40 hours a week</p> </td> </tr> <tr> <td data-bbox="418 1352 578 1629">Occupational</td> <td data-bbox="578 1352 1008 1629"> <p>CDC, NIOSH Recommended Exposure Level (REL): 85 dBA over 8 hours daily</p> <p>OSHA Permissible Exposure Limit (PEL): 90 dBA over 9 hours daily</p> <p>NIDCD: ≤ 70 dBA is safe; > 85 dBA is damaging over time</p> </td> </tr> <tr> <td data-bbox="418 1629 578 1730">Military</td> <td data-bbox="578 1629 1008 1730"> <p>US ARL: SPL <i>shall not</i> exceed an 8-hour time weighted average of 85 dBA</p> </td> </tr> </tbody> </table> <p>Table 1: Describes different hearing standards for different types of exposures.</p>	Exposure type	Standard	Recreational (audio device)	<p>WHO-ITU (H.870)</p> <p>Adults: 80 dBA for 40 hours a week</p> <p>Children: 75 dBA for 40 hours a week</p>	Occupational	<p>CDC, NIOSH Recommended Exposure Level (REL): 85 dBA over 8 hours daily</p> <p>OSHA Permissible Exposure Limit (PEL): 90 dBA over 9 hours daily</p> <p>NIDCD: ≤ 70 dBA is safe; > 85 dBA is damaging over time</p>	Military	<p>US ARL: SPL <i>shall not</i> exceed an 8-hour time weighted average of 85 dBA</p>
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Military	<p>US ARL: SPL <i>shall not</i> exceed an 8-hour time weighted average of 85 dBA</p>								

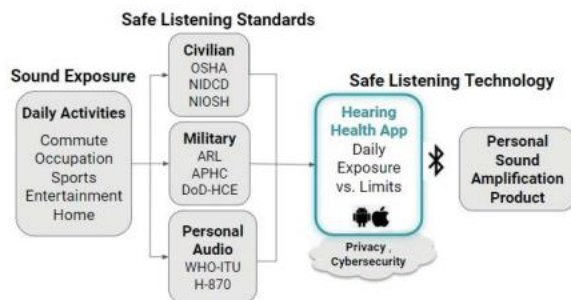


Figure 1 – Hearing Health app overview

Figure 1: Places the sound exposure and standards and response into a flowchart to show the function of the app

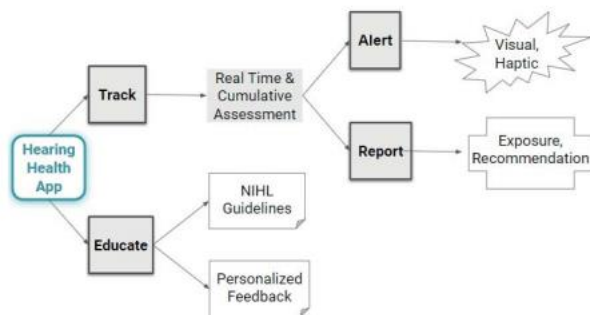


Figure 2 – Hearing Health app functionalities

Figure 2: Detailed flowchart of the response and function of the app.

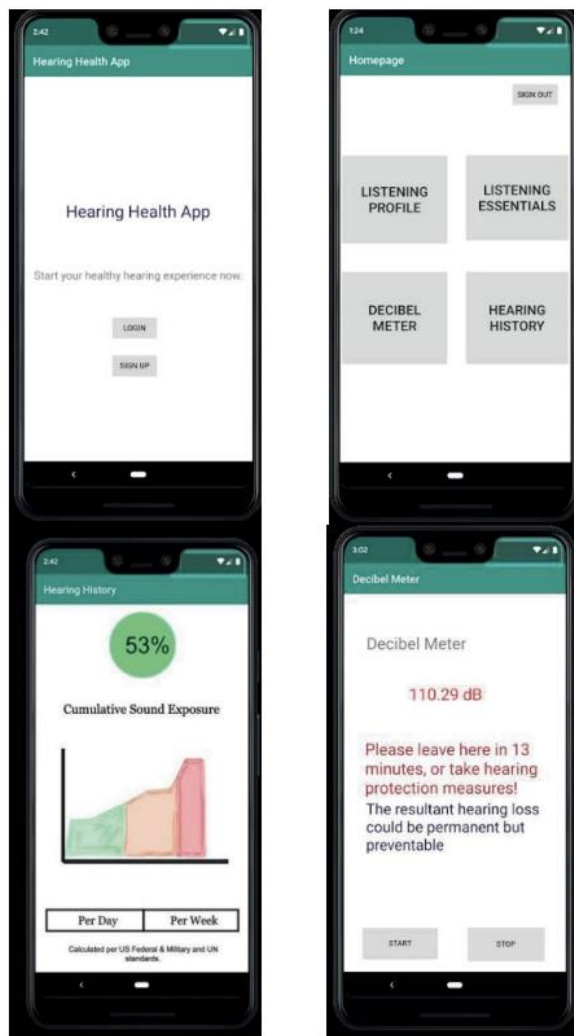


Figure 3: Pictures of the app and its UI

VOCAB: (w/definition)

Noise-Induced Hearing Loss (NIHL) - Permanent hearing damage caused by prolonged exposure to loud sounds exceeding safe listening thresholds.

A-weighted Sound Pressure Level (dBA) - A sound measurement that reflects how humans perceive loudness by adjusting for ear sensitivity to different frequencies.

m-Health (Mobile Health) - The use of mobile and wireless tech to support health practices, medical monitoring, and public health goals.

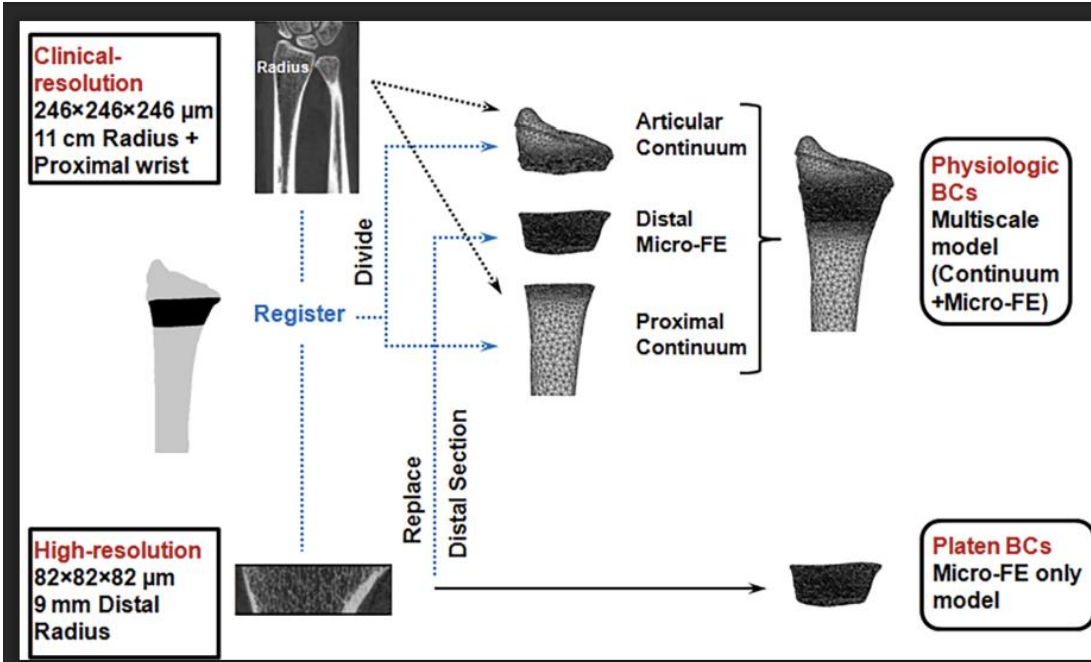
Personal Sound Amplification Product (PSAP) - A consumer device that amplifies sounds for users without diagnosed hearing loss; in this study, use to enhance sound measurement accuracy

Cited references to follow up on	<ol style="list-style-type: none">1. NIOSH Occupational noise exposure, revised criteria, 1998: https://www.cdc.gov/niosh/docs/98-126/pdfs/98-126.pdf?id=10.26616/NIOSH PUB981262. J. Eichwald, F. Scinicariello, J.L. Teffer, and Y.I. Carroll. "Use of personal hearing protection devices at loud athletic or entertainment events among adults – United States, 2018. Morbidity and Mortality Weekly Report, vol. 67 no. 41, pp 1151-1155, 2018.
Follow up Questions	<ol style="list-style-type: none">1. How effective is the Hearing Health app in changing users' long-term listening behaviors and reducing real-world NIHL risk after extended use?2. Could integration with wearable sensors (e.g., smart earbuds or watches) improve the accuracy and personalization of real-time sound exposure monitoring?3. What design modifications are needed to adapt the app for users with existing hearing impairments or hearing aids, ensuring accessibility and clinical utility?

Article #7 Notes: Simplified boundary conditions alter cortical trabecular load sharing at the distal radius; a multiscale finite element analysis

Article notes should be on separate sheets

Source Title	Simplified boundary conditions alter cortical-trabecular load sharing at the distal radius; A multiscale finite element analysis
Source citation (APA Format)	Johnson, J. E., & Troy, K. L. (2018). Simplified boundary conditions alter cortical-trabecular load sharing at the distal radius: A multiscale finite element analysis. <i>Journal of Biomechanics</i> , 66, 180–185. https://doi.org/10.1016/j.jbiomech.2017.11.025
Original URL	https://www.sciencedirect.com/science/article/abs/pii/S0021929017305766?via%3Dihub
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	This study investigated how different boundary conditions (ways of applying force or constraints in a model) affect how loads are distributed between cortical (outer) and trabecular (inner) bone at the distal radius (wrist bone). Researchers compared simplified platen-compression boundary conditions, which simulate the bone being squeezed between two flat plates, with more realistic physiological boundary conditions that mimic natural loading through the wrist joint. Using high-resolution peripheral quantitative computed tomography (HR-pQCT) scans of nine cadaveric forearms, they built multiscale finite element (FE) models to simulate both types of conditions. Cortical and trabecular load sharing and strain distributions were analyzed along a 9 mm section of bone using

	<p>Abaqus software and mathematical correlations. The study found that while both boundary conditions produced generally correlated results, platen compression overestimated cortical loads by up to 30% distally and underestimated trabecular loads by up to 53% proximally. The distribution of strains also differed, meaning the simplified model did not accurately reflect real-world bone behavior. These findings suggest that standardized platen-compression models, though convenient, may misinterpret physiological load sharing, and results from such models should be interpreted carefully when used in clinical or biomechanical evaluations.</p>
<p>Research Question/Problem/ Need</p>	<p>Can simplified platen-compression simulations accurately represent how the cortical and trabecular regions of the distal radius load under realistic, physiological conditions, or do they distort the mechanical behavior observed in real bone?</p>
<p>Important Figures</p>	 <p>Figure 1: This figure lays out a multiscale modeling framework for the distal radius (wrist) bone, showing how data from clinical high-resolution scans (and mechanical properties measurements are integrated through steps like registration and segmentation.) Two analysis paths:</p> <ul style="list-style-type: none"> • One uses high-resolution micro-FE (finite element) models based on micro-CT for detailed local mechanical behavior. • Another uses continuum models for larger scale more anatomical regions of the bone.

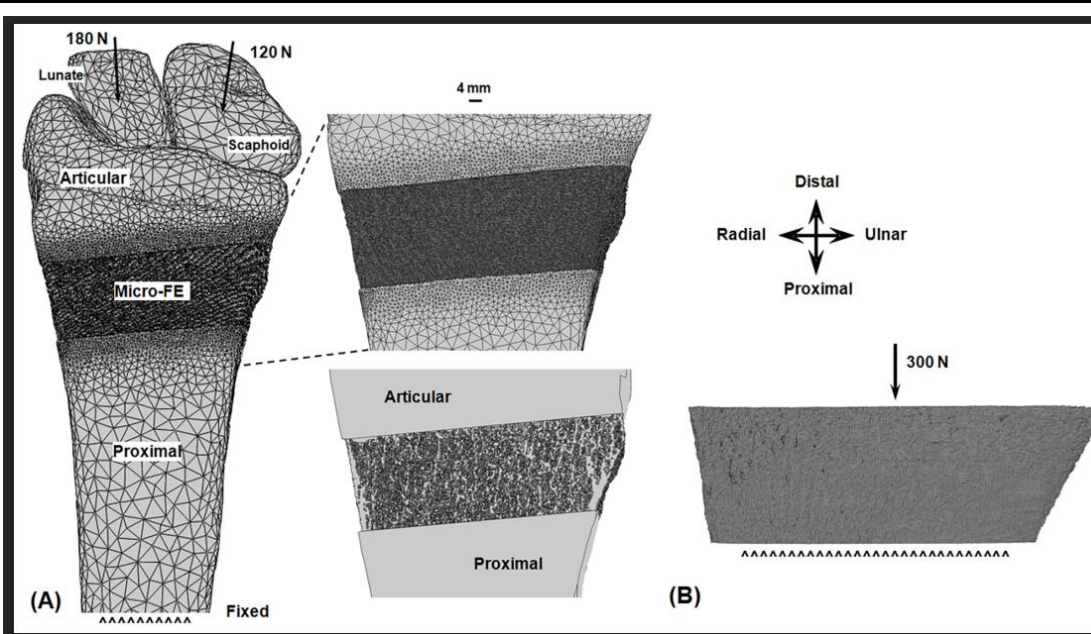
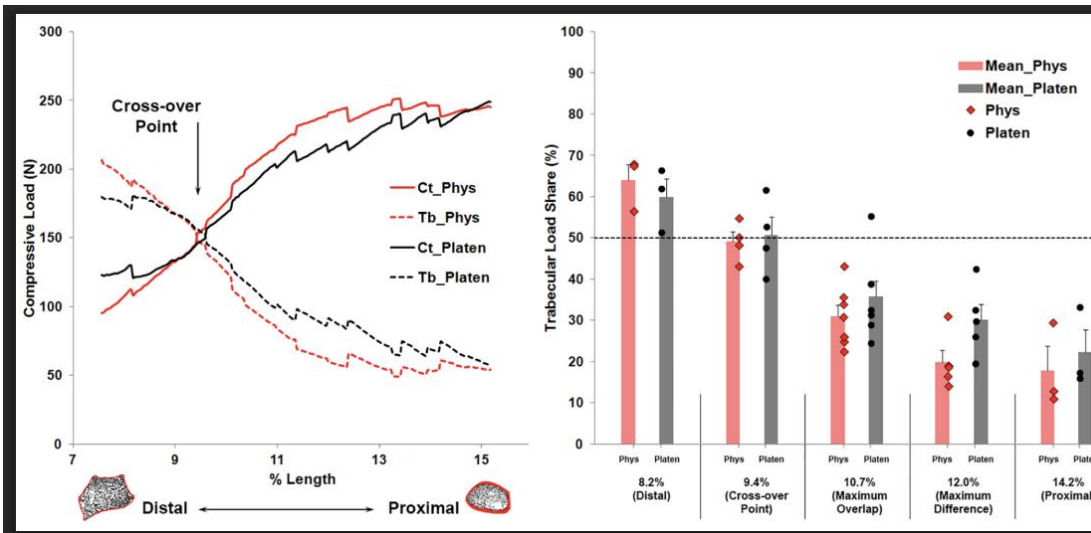


Figure 2: (A) Visualizes the geometry and mesh of the distal radius in 3D—mesh representations are crucial for running finite element simulations. The full bone is shown with the region of interest highlighted. (B) Shows a zoomed view of a sectioned mesh, detailing how the computational domain is defined for simulation. Different slices correspond to different regions (proximal, distal, etc.) showing readiness for the application of various loading boundary conditions.

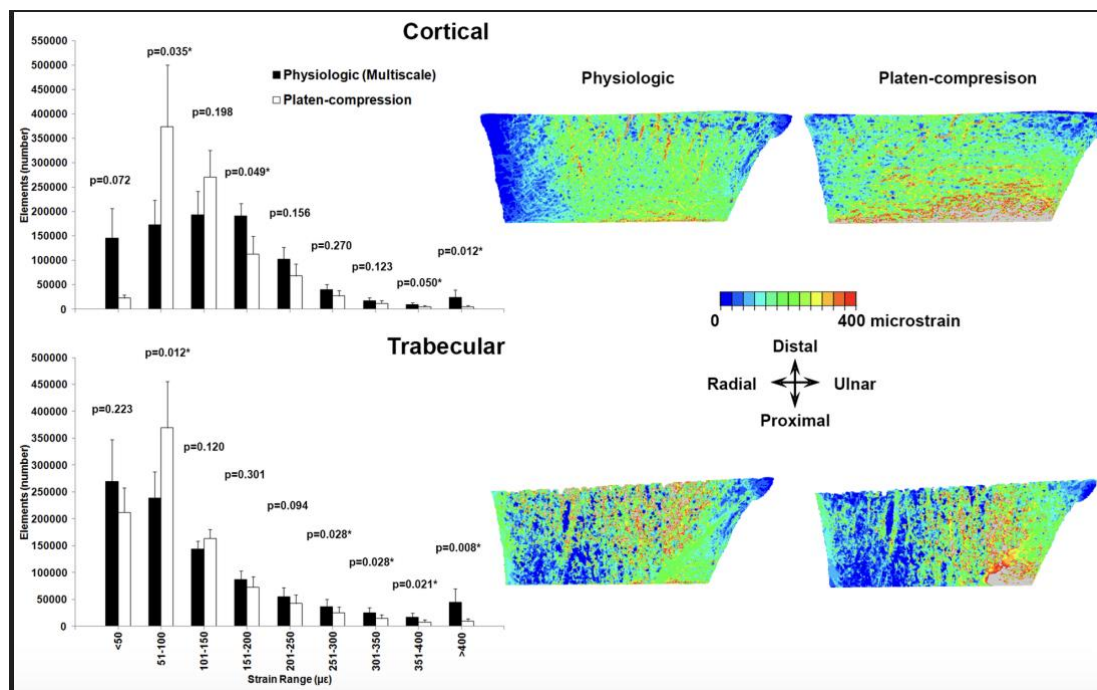


Figures 5 & 6:

Top Left: A plot showing a crossover point in a graph of material or stress properties along the radius length, presumably contrasting parameters such as density, modulus, or mechanical performance versus bone location (distal to proximal)

Top Right: Bar graphs comparing mechanical outcomes or tissue property data (possibly strength, stiffness, etc.) for different modeling regions or experiment groups. Distinct color

coding and asterisks may indicate significant differences across groups or conditions.



Figures 7 & 8:

Bar graphs (Left): Quantifies specific mechanical or performance metrics for different radius regions ('Cortical' and 'Trabecular' bone) experimental groups or loading scenarios. Statistical significance is indicated for some comparisons

Color Maps (Right): Simulation output showing finite element stress/strain distributions under different boundary conditions (Physiologic, Platen compression) for both cortical (top) and trabecular (bottom) compartments of the radius. The color bar legend and annotation help interpret load distribution and mechanical "hot spots" under different scenarios.

VOCAB: (w/definition)

Finite Element Analysis (FEA) - A computational method that divides a structure into many small elements to predict how it responds to forces, stresses, and strains.

Boundary Conditions – Constraints or external forces applied to a model that define how it interacts with its environment during simulation.

Cortical Bone – The dense, hard outer layer of bone that provides strength and structure.

Trabecular Bone – The spongy, porous inner layer of bone that absorbs shock and supports load transfer.

Cited references to follow up on

1. Edwards, W. B., & Troy, K. L. (2011). Simulating distal radius fracture strength using biomechanical tests: A modeling study examining the

	<p>influence of boundary conditions. <i>Journal of Biomechanical Engineering</i>, 133(11), 114501. https://doi.org/10.1115/1.4005473</p> <p>2. Schaffler, M. B., Radin, E. L., & Burr, D. B. (1990). Long-term fatigue behavior of compact bone at low strain magnitude and rate. <i>Bone</i>, 11(5), 321–326. https://doi.org/10.1016/8756-3282(90)90163-E</p>
<p>Follow up Questions</p>	<ol style="list-style-type: none"> 1. How would including muscle forces and joint contact dynamics further improve the accuracy of physiologic boundary condition models? 2. Would similar load-sharing differences be observed in bones other than the distal radius, such as the tibia or femur? 3. How do variations in bone quality (age, osteoporosis) affect the accuracy of platen-compression simulations compared to physiologic models?

Article #8 Notes: Effectiveness of Mobilization of the Talus and Distal Fibula in the Management of Acute Lateral Ankle Sprain

Article notes should be on separate sheets

<p>Source Title</p>	<p>Effectiveness of Mobilization of the Talus and Distal Fibula in the Management of</p>
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	Acute Lateral Ankle Sprain
Source citation (APA Format)	Izaola-Azkona, L., Vicenzino, B., Olabarrieta-Eguia, I., Saez, M., & Lascurain-Aguirrebeña, I. (2021). Effectiveness of mobilization of the talus and distal fibula in the management of acute lateral ankle sprain. <i>Physical Therapy</i> , 101(8). https://doi.org/10.1093/ptj/pzab111
Original URL	https://academic.oup.com/ptj/article/101/8/pzab111/6231218?login=false
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	This paper compares three manual therapy interventions, anteroposterior mobilization of the talus (MOB), distal fibular mobilization with movement (MWM), and MWM plus posterior gliding fibular tape (MWMtape), to treat acute lateral ankle sprain in amateur soccer players. In a double-blind randomized controlled trial, all groups also received general self-management advice, electrotherapy, massage for swelling, and a proprioception exercise program. While all intervention resulted in improvement, MWM and MWMtape produced greater long-term gains in function according to the Foot and Ankle Ability Measure (FAAM) than MOB, whereas MOB yielded superior sport function at 2 weeks. The addition of the fibular tape did not enhance outcomes and there were no substantial differences between groups for pain, pressure pain threshold, RoM or strength.
Research Question/Problem / Need	Which manual therapy technique—MOB, MWM, or MWMtape— is most effective for functional recovery (both short and long term) for acute grade II lateral ankle sprain in amateur soccer players?

Important Figures

Table 1. Participant Characteristics at Baseline^a

	MOB	MWM	MWM+tape	All
Age, y	24.1 [5.1]	25.4 [5.6]	22.7 [5.1]	24.1 [5.3]
Height, cm	174.7 [5.4]	178.8 [4.7]	174.9 [8.9]	176.2 [6.6]
Mass, kg	73.1 [9.3]	76.5 [10.2]	70.8 [7.5]	73.6 [9.2]
Sex (male/female)	12/3	16/0	13/1	41/4
Responder ^b (yes/no)	9/6	9/7	6/8	24/21
FAAM ADL subscale (0–100)	51.1 [20.4]	45.3 [22.7]	36.9 [12.7]	44.6 [19.8]
Global rating of ADL function (0–100)	46.4 [16.9]	48.3 [27.2]	45.8 [23.2]	46.9 [22.4]
FAAM sport subscale (0–100)	22.35 [17.6]	13.7 [17.9]	8.26 [11.2]	14.9 [16.7]
Global rating of sport function (0–100)	18.57 [17]	13.6 [19.7]	13.6 [16.2]	15.2 [17.5]
Maximum pain (0–10)	6.2 [1.8]	5.5 [2.6]	6.8 [2.2]	6.2 [2.3]
Average pain (0–10)	3.6 [1.4]	3.4 [1.9]	4.8 [2.1]	3.9 [1.9]
PPT, N	36.7 [8.9]	37.7 [9.4]	32.9 [11.1]	35.8 [9.8]
Volume, mL	1379.9 [185.1]	1388.2 [155.5]	1389.9 [131.8]	1386 [155.8]
ROM dorsiflexion, cm	1 [4.9]	1.8 [4.2]	1 [6.7]	1.3 [5.2]
ROM plantarflexion, degrees	34 [4.9]	33 [6.6]	31.8 [4.7]	33 [5.5]
ROM inversion, degrees	15.5 [5.3]	13.1 [4.7]	16.5 [4.4]	15 [4.9]
ROM eversion, degrees	6.3 [2.7]	4.9 [3.3]	6.7 [2.6]	5.9 [3]
Eversion strength, N	9.5 [2.9]	7.5 [2.9]	7.5 [2.7]	8.2 [2.9]

^aValues are mean [SD] unless otherwise indicated. ADL = activities of daily living; FAAM = foot and ankle ability measure; MOB = anteroposterior mobilization of the talus; MWM = distal fibular mobilization with movement; MWM+tape = distal fibular mobilization with movement plus tape; PPT = pressure pain threshold; ROM = range of movement. ^bResponder to distal fibular repositioning maneuver.

Table 1: Presents the demographics, injury characteristics, and initial functional and clinical scores for each treatment group. Groups started with similar baseline measures, supporting fair comparison.

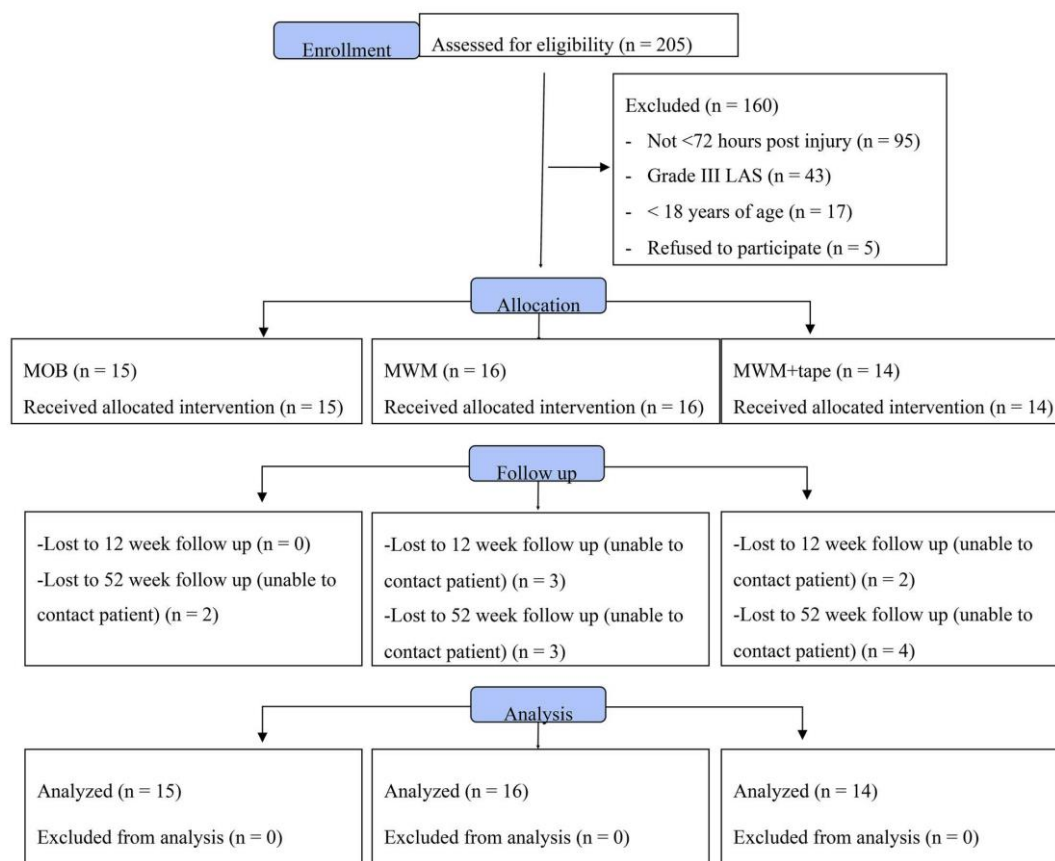


Figure. CONSORT flow diagram. LAS = lateral ankle sprain; MOB = anteroposterior mobilization of the talus; MWM = distal fibular mobilization with movement.

Figure 1: Illustrates the process of eligible participant recruitment, random allocation,

intervention assignment, and analysis.

Table 2. FAAM ADL and Sport Subscale Scores for MOB, MWM, and MWMtape Groups^a

	MOB	MWM	MWMtape
FAAM ADL subscale			
2 wk	86.3 [14]	89.1 [9.7]	86.3 [8.3]
5 wk	94.6 [6.4]	95.8 [6.4]	95.4 [5.6]
12 wk	97.9 [3.1]	99.2 [1.6]	98.6 [2]
52 wk	99.9 [0.3]	100 [0]	99.8 [0.8]
FAAM sport subscale			
2 wk	61.9 [26.1]	55.8 [21.5]	46.3 [26.4]
5 wk	83.7 [16.8]	79.8 [20.9]	72.9 [29.4]
12 wk	92.6 [10.2]	93.1 [13.9]	94.3 [8.1]
52 wk	99.7 [0.9]	100 [0]	98.5 [2.6]

^aValues are mean [SD]. ADL = activities of daily living; FAAM = foot and ankle ability measure; MOB = anteroposterior mobilization of the talus; MWM = distal fibular mobilization with movement; MWMtape = distal fibular mobilization with movement plus tape; PPT = pressure pain threshold; ROM = range of movement.

Table 2: Shows the progression of self-reported ability scores (mean and SD) for daily tasks and sports activities at 2, 5, 12, and 52 weeks for each therapy group. Visualizes which interventions lead to faster or more durable functional gains.

Table 3. Differences in FAAM ADL Subscale and Global Rating of ADL Function Between Groups at 2, 5, 12, and 52 Weeks^a

	Coefficient	95% Credibility Interval	P
ADL subscale			
MWM, 2 wk	0.22	-6.51 to 6.06	.52
MWM, 5 wk	6.28	0 to 12.56	.97 ^b
MWM, 12 wk	8.84	2.38 to 15.28	.99 ^b
MWM, 52 wk	9.90	3.45 to 16.33	.99 ^b
MWMtape, 2 wk	-1.19	-7.54 to 5.15	.64
MWMtape, 5 wk	7.63	1.29 to 13.96	.99 ^b
MWMtape, 12 wk	10.85	4.39 to 17.30	.99 ^b
MWMtape, 52 wk	11.59	4.94 to 18.23	.99 ^b
Global rating of ADL function			
MWM, 2 wk	-3.19	-10.05 to 3.66	.82
MWM, 5 wk	5.11	-1.68 to 11.9	.92
MWM, 12 wk	8.53	1.45 to 15.57	.99 ^b
MWM, 52 wk	10.08	3.03 to 17.09	.99 ^b
MWMtape, 2 wk	-4.21	-11.22 to 2.77	.88
MWMtape, 5 wk	8.07	1.06 to 15.06	.98 ^b
MWMtape, 12 wk	7.32	0.02 to 14.65	.97 ^b
MWMtape, 52 wk	9.65	2.72 to 17	.99 ^b

^aAdjusted for the effect of age, sex, body mass index, and baseline value. Coefficient indicates difference with respect to reference intervention, MOB = anteroposterior mobilization of the talus; MWM = distal fibular mobilization with movement; MWMtape = distal fibular mobilization with movement plus tape. ^bP > .95.

Table 3: Lists observed differences and confidence intervals between groups at specific time points, helping us see precisely when and by how much groups differed in the daily living function.

Table 4. Differences in FAAM Sport Subscale and Global Rating of Sport Function Between Groups at 2, 5, 12, and 52 Weeks^a

	Coefficient	95% Credibility Interval	P
Sport subscale			
MWM, 2 wk	-16.5	-26.3 to -6.65	.99 ^b
MWM, 5 wk	2.71	-7.27 to 12.65	.70
MWM, 12 wk	11.97	1.54 to 22.30	.98 ^b
MWM, 52 wk	18.81	8.37 to 29.14	.99 ^b
MWMtape, 2 wk	-20.93	-30.94 to -10.63	.99 ^b
MWMtape, 5 wk	0.42	-9.68 to 10.51	.53
MWMtape, 12 wk	16.69	5.85 to 27.42	.99 ^b
MWMtape, 52 wk	18.01	6.84 to 29.05	.99 ^b
Global rating of sport function			
MWM, 2 wk	-12.11	-22.14 to -2.04	.99 ^b
MWM, 5 wk	4.07	-6.15 to 14.26	.78
MWM, 12 wk	14.4	3.68 to 25.02	.99 ^b
MWM, 52 wk	17.89	7.33 to 28.33	.99 ^b
MWMtape, 2 wk	-22.54	-32.94 to -12.05	.99 ^b
MWMtape, 5 wk	3.23	-7.41 to 13.82	.72
MWMtape, 12 wk	13.5	2.28 to 24.6	.99 ^b
MWMtape, 52 wk	14.28	3 to 25.44	.99 ^b

^aAdjusted for the effect of age, sex, body mass index, and baseline value. Coefficient indicates difference with respect to reference intervention, MOB. FAAM=foot and ankle ability measure; MOB=anteroposterior mobilization of the talus; MWM=distal fibular mobilization with movement; MWMtape=distal fibular mobilization with movement plus tape. ^bP > .95.

Table 4: Similar to table 3 but focuses on sports related function, indicating whether initial sport improvement (with MOB) persists or shifts over time.

Table 5. Pain, PGI-I, PPT, ROM, Volume, and Strength, at 2, 5, 12, and 52 Weeks^a

	MOB			MWM			MWMtape		
	2 Wk	5 Wk	12 Wk	2 Wk	5 Wk	12 Wk	2 Wk	5 Wk	12 Wk
PGI-I	6	6	6	6	6	7	6	7	6
Maximum pain ^b	1.4 [1.2]	0.8 [0.7]	0.7 [1.5]	1.5 [1.1]	0.9 [1.7]	0.1 [0.3]	1.6 [1.4]	0.9 [1.2]	0.6 [1.1]
Average pain ^b	0.9 [1]	0.5 [0.6]	0.5 [1.4]	0.9 [0.7]	0.5 [1]	0 [0.1]	0.9 [1.2]	0.4 [0.7]	0.3 [0.6]
PPT, N	40.3 [5.7]	43.5 [5]	41.8 [6.4]	40.2 [5.2]	40.3 [4.4]	41.8 [5.7]	38.7 [4.3]	42.7 [4.7]	43.2 [5.3]
Volume, mL	1329.7 [196.6]	NR	NR	1344.7 [144.5]	NR	NR	1318.9 [138.1]	NR	NR
ROM dorsiflexion, cm	3.4 [4.5]	NR	NR	3.5 [3.7]	NR	NR	3.6 [3.5]	NR	NR
ROM plantarflexion, degrees	37.9 [5.3]	NR	NR	37.1 [6.9]	NR	NR	37.8 [6.2]	NR	NR
ROM inversion, degrees	16.3 [5.1]	NR	NR	13.5 [3.6]	NR	NR	14.9 [5.6]	NR	NR
ROM eversion, degrees	8.9 [2.7]	NR	NR	9.1 [1.6]	NR	NR	9.7 [4.3]	NR	NR
Eversion strength, N	10.4 [2.9]	11.3 [2.8]	NR	10.4 [3.5]	10.5 [3.5]	NR	10.7 [4]	12.4 [4.5]	NR

^aValues are mean [SD] for all variables except PGI-I, where median is shown. MOB=anteroposterior mobilization of the talus; MWM=distal fibular mobilization with movement; MWMtape=distal fibular mobilization with movement plus tape; NR, not recorded; PGI-I=Patient Global Impression of Improvement Scale; PPT=pressure pain threshold; ROM=range of movement. ^b0-10 scale.

Table 5: Compares pain ratings, perceived global improvement, pressure pain threshold, ankle movements, swelling, and muscle strength for each group at each follow-up. It shows that aside from functional scores, most clinical measures were similar between interventions.

**VOCAB:
(w/definition)**

Mobilization with Movement (MWM): A physical therapy technique where the therapist applies a sustained glide to a joint while the patient actively moves the limb aiming to restore movement and reduce pain.

Anteroposterior Mobilization of the Talus (MOB): A manual therapy technique involving oscillatory movement of the talus in the ankle joint directed from front to back to improve mobility.

	<p>Foot and Ankle Ability Measure (FAAM): A self-reported questionnaire assessing a patient's ability to perform activities of daily living and sports tasks following foot or ankle injuries.</p> <p>Pressure Pain Threshold (PPT): The minimum amount of force applied to a specific body area that elicits pain used as an objective measure in musculoskeletal research.</p>
<p>Cited references to follow up on</p>	<ol style="list-style-type: none"> 1. Hudson, R., Baker, R. T., May, J., et al. (2017). Novel treatment of lateral ankle sprains using the Mulligan concept: An exploratory case series analysis. <i>Journal of Manual & Manipulative Therapy</i>, 25(5), 251–259. 2. Cosby, N. L., Koroch, M., Grindstaff, T. L., et al. (2011). Immediate effects of anterior to posterior talocrural joint mobilizations following acute lateral ankle sprain. <i>Journal of Manual & Manipulative Therapy</i>, 19(2), 76–83.
<p>Follow up Questions</p>	<ol style="list-style-type: none"> 1. How might combining MWM and MOB within a treatment period affect functional recovery compared to using each separately 2. What role did patient adherence to the proprioception exercise program play in the observed differences between groups, especially at long-term follow up? 3. Would similar trends in effectiveness be expected in older adults or in patients with chronic ankle sprains, rather than acute injuries in athletes?

Article #9 Notes: Comparison of three preventative methods in order to reduce the incidence of ankle inversion sprains among female volleyball players

Article notes should be on separate sheets

Source Title	Comparison of three preventative methods in order to reduce the incidence of ankle inversion sprains among female volleyball players
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Source citation (APA Format)	Stasinopoulos, D. (2004). Comparison of three preventive methods in order to reduce the incidence of ankle inversion sprains among female volleyball players. <i>British Journal of Sports Medicine</i> , 38(2), 182–185. https://doi.org/10.1136/bjism.2002.003947														
Original URL	https://bjsm.bmj.com/content/38/2/182														
Source type	Journal Article														
Keywords															
#Tags															
Summary of key points + notes (include methodology)	This study evaluated three preventative methods, technical training, proprioceptive training, and the use of an orthosis (ankle brace, to reduce the incidence of ankle inversion sprains among female volleyball players with a previous history of sprain. Players were randomized into one of the three interventions and monitored over a season. All strategies reduced the likelihood of a new sprain, with technical training being slightly more effective overall. However, in players who had four or more previous sprains, orthosis was ineffective, while technical and proprioceptive training remained beneficial. These findings highlight the importance of tailoring prevention strategies to an athlete's injury history, suggesting that training focused methods are the most effective in highly recurrent cases.														
Research Question/Problem/Need	Which of the three preventative strategies—technical training, proprioceptive training, or the use of orthosis—is most effective at preventing future ankle sprain in female volleyball players with a prior history of this injury?														
Important Figures	<table border="1" data-bbox="375 1289 1390 1514"> <caption>Table 1 Players' characteristics</caption> <thead> <tr> <th>n</th> <th>Age (years)</th> <th>Height (cm)</th> <th>Weight (kg)</th> <th>Experience (years)</th> <th>Training/week (hours)</th> <th>Matches/year</th> </tr> </thead> <tbody> <tr> <td>52</td> <td>23 (3)</td> <td>180.6 (4.50)</td> <td>69.28 (5.59)</td> <td>10.4 (3.12)</td> <td>10.28 (2.39)</td> <td>29 (9.33)</td> </tr> </tbody> </table> <p>Values are mean (SD).</p> <p>Table 1: Summarizes the physical profiles and training workloads of the 52 volleyball players. Groups were similar at baseline for fair comparison</p>	n	Age (years)	Height (cm)	Weight (kg)	Experience (years)	Training/week (hours)	Matches/year	52	23 (3)	180.6 (4.50)	69.28 (5.59)	10.4 (3.12)	10.28 (2.39)	29 (9.33)
n	Age (years)	Height (cm)	Weight (kg)	Experience (years)	Training/week (hours)	Matches/year									
52	23 (3)	180.6 (4.50)	69.28 (5.59)	10.4 (3.12)	10.28 (2.39)	29 (9.33)									

Table 2 Frequency of ankle sprain in volleyball players during their careers

Players	Number of sprains
12 (23%)	1
12 (23%)	2
12 (23%)	3
10 (19%)	4
6 (12%)	>4

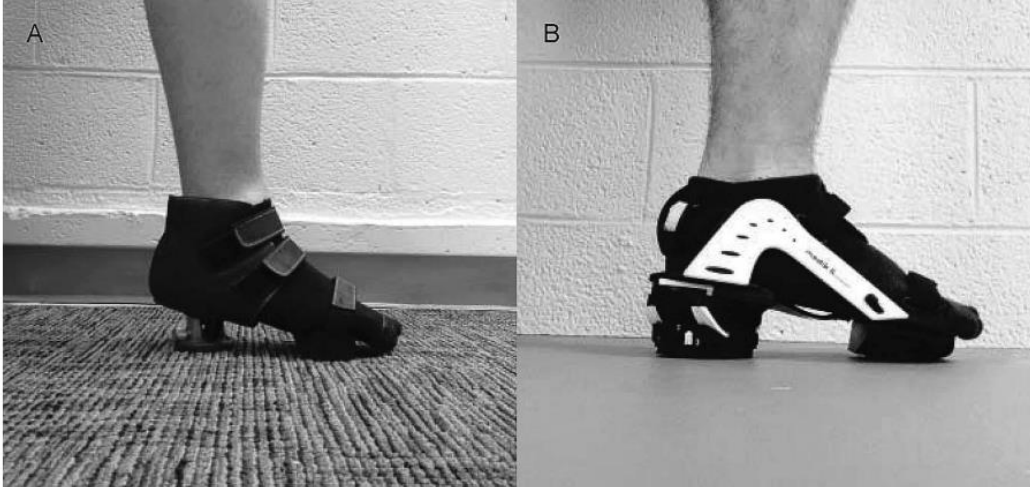
Table 2: Categorizes participants by the number of times they had suffered an ankle sprain prior to the study. Important for understanding how each prevention strategy performs across different risk levels.

<p>VOCAB: (w/definition)</p>	<p>Proprioceptive Training: Exercise regime designed to improve balance, joint position awareness, and neuromuscular adaptations that help prevent injury recurrence by using tools like balance boards.</p> <p>Orthosis: An external support, such as an ankle brace, worn to stabilize a joint and potentially prevent reinjury during physical activity.</p> <p>Technical Training: Specific coaching that focuses on improving the skills and movement techniques (takeoff and landing) used in volleyball to avoid mechanisms of injury.</p> <p>Inversion Sprain: A type of ankle injury in which the foot turns inward, commonly resulting in sprained ligaments on the outer side of the ankle.</p>
<p>Cited references to follow up on</p>	<ol style="list-style-type: none"> 1. Bahr, R., Lian, O., & Bahr, I. A. (1997). A twofold reduction in the incidence of acute ankle sprains in volleyball after the introduction of an injury prevention program: A prospective cohort study. <i>Scandinavian Journal of Medicine & Science in Sports</i>, 7(3), 172–177. 2. Bahr, R., & Bahr, I. A. (1997). Incidence of acute volleyball injuries: A prospective cohort study of injury mechanisms and risk factors. <i>Scandinavian Journal of Medicine & Science in Sports</i>, 7(3), 166–171.
<p>Follow up Questions</p>	<ol style="list-style-type: none"> 1. Would a combined intervention program (mixing proprioceptive, technical, and orthosis approaches) be more efficient than any single method alone for athletes with multiple prior sprains? 2. How does compliance with the prevention programs change over time, and what strategies would improve long-term adherence among players and coaches? 3. Could the same findings be extended to male volleyball players or players at other competitive levels (1st division) or those with no prior ankle sprains?

Article #10 Notes: Rehabilitation for Chronic Ankle Instability with or Without Destabilization Devices: A Randomized Controlled Trial

Article notes should be on separate sheets

Source Title	Rehabilitation for Chronic Ankle Instability With or Without Destabilization Devices: A Randomized Controlled Trial
Source citation (APA Format)	Donovan, L., Hart, J. M., Saliba, S. A., Park, J., Feger, M. A., Herb, C. C., & Hertel, J. (2016). Rehabilitation for chronic ankle instability with or without destabilization devices: A randomized controlled trial. <i>Journal of Athletic Training, 51</i> (3), 233–251. https://doi.org/10.4085/1062-6050-51.3.09
Original URL	https://nata.kglmeridian.com/view/journals/attr/51/3/article-p233.xml?body=PDF
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	This paper reports a randomized controlled trial evaluating whether adding ankle destabilization devices to impairment-based progressive rehabilitation yields greater recovery for chronic ankle instability (CAI) than standard rehabilitation with traditional unstable surfaces. Twenty-six participants with CAI were split into device and no-device groups, both receiving a 4-week supervised rehabilitation program emphasizing range of

	<p>motion, strength, balance, and function exercises. The main outcomes measured were self-reported function, RoM, strength and balance. Both groups showed substantial improvements, but there was no significant difference between groups destabilization devices did not result in better outcomes than traditional unstable surfaces. Improvements were most evident in self-reported function, strength, and motor-unit recruitment.</p>
Research Question/Problem / Need	<p>Does incorporating ankle destabilization devices into a 4-week impairment-based progressive rehabilitation program offer greater benefits for self-reported ankle function, RoM, strength, and balance compared to typical rehabilitation using unstable surfaces for patients with CAI?</p>
Important Figures	 <p>Figure 1 consists of two side-by-side photographs, labeled A and B. Photograph A shows a person's lower leg and foot wearing a black, high-top ankle boot with two horizontal straps across the ankle. The boot is on a carpeted floor. Photograph B shows a person's lower leg and foot wearing a black and white sandal with a complex, multi-layered sole and a white plastic brace that wraps around the ankle and heel. The sandal is on a smooth, light-colored floor.</p> <p>Figure 1: Photos of the destabilization devices used, emphasizing differences between the boot and a sandal.</p>

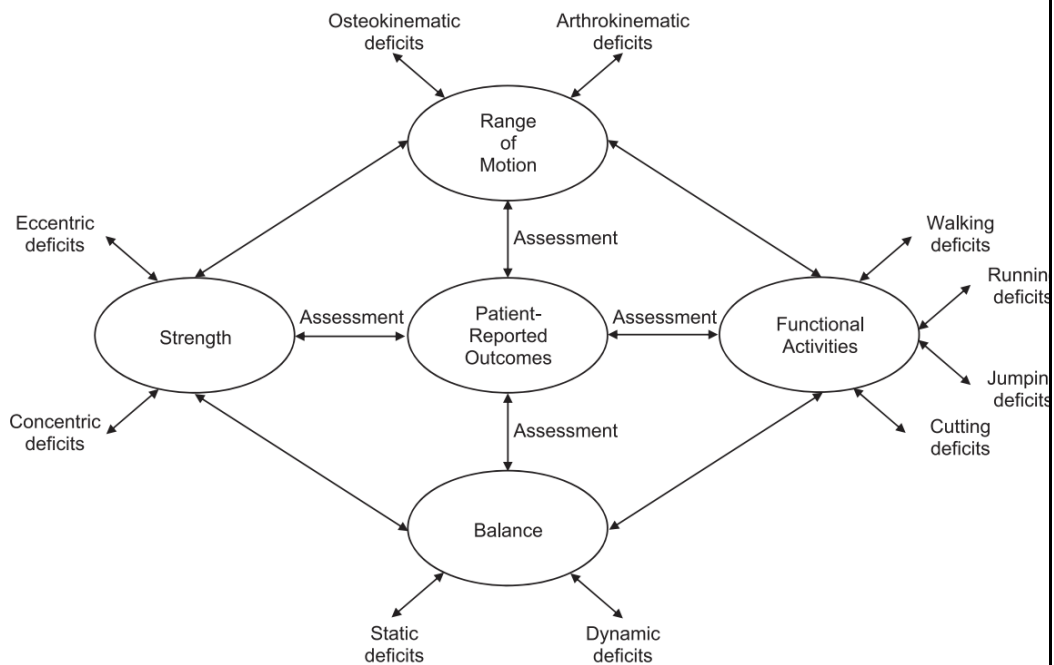


Figure 2. Modification to the rehabilitation paradigm to include self-reported function. Donovan L, Hertel J. A new paradigm for rehabilitation of patients with chronic ankle instability. *Phys Sportsmed.* 2012;40(4):41–51. Reprinted by permission of the publisher Taylor & Francis Ltd, www.tandfonline.com.

Figure 2: A flowchart showing the rehab model progression, emphasizing “assess, treat, re-assess” in four domains (functional, RoM, strength, balance)

Table 1. Dependent Variables Organized by Patient-Oriented, Clinically Oriented, and Laboratory-Oriented Outcomes

Patient Oriented ^a	Subscale	Outcomes								
		Clinically Oriented			Strength Surface Electromyography Amplitude			Balance Surface Electromyography Amplitude		
		Range of Motion	Strength	Balance	Task	Muscle(s)	Task	Muscles	Task	Force Plate
Foot and Ankle Ability Measure	Activities of Daily Living	Dorsiflexion with straight knee and bent knee	Dorsiflexion	Star Excursion Balance Test	Dorsiflexion	Anterior tibialis	Eyes-open balance	Anterior tibialis, peroneus brevis, peroneus longus, and medial gastrocnemius	Eyes-open balance	COP area and velocity
	Sport	Inversion	Inversion		Inversion	Anterior tibialis	Eyes-closed balance	Anterior tibialis, peroneus brevis, peroneus longus, and medial gastrocnemius	Eyes-closed balance	COP area and velocity
Single Assessment Numeric Evaluation	Activities of Daily Living	Eversion	Eversion		Eversion	Peroneus brevis and peroneus longus	Star Excursion Balance Test	Anterior tibialis, peroneus brevis, peroneus longus, and medial gastrocnemius		
	Sport	Plantar flexion	Eversion in plantar flexion		Eversion in plantar flexion	Peroneus brevis and peroneus longus				
Global rating of change			Plantar flexion		Plantar flexion	Medial gastrocnemius				

Abbreviation: COP, center of pressure.
^a Self-reported function.

Table 1: A matrix organizing all measured outcomes (patient-oriented, clinically-oriented,

lab-oriented), including details like specific tasks, muscle groups, and the types of measurements (FAAM scales, sEMG, balance tests)

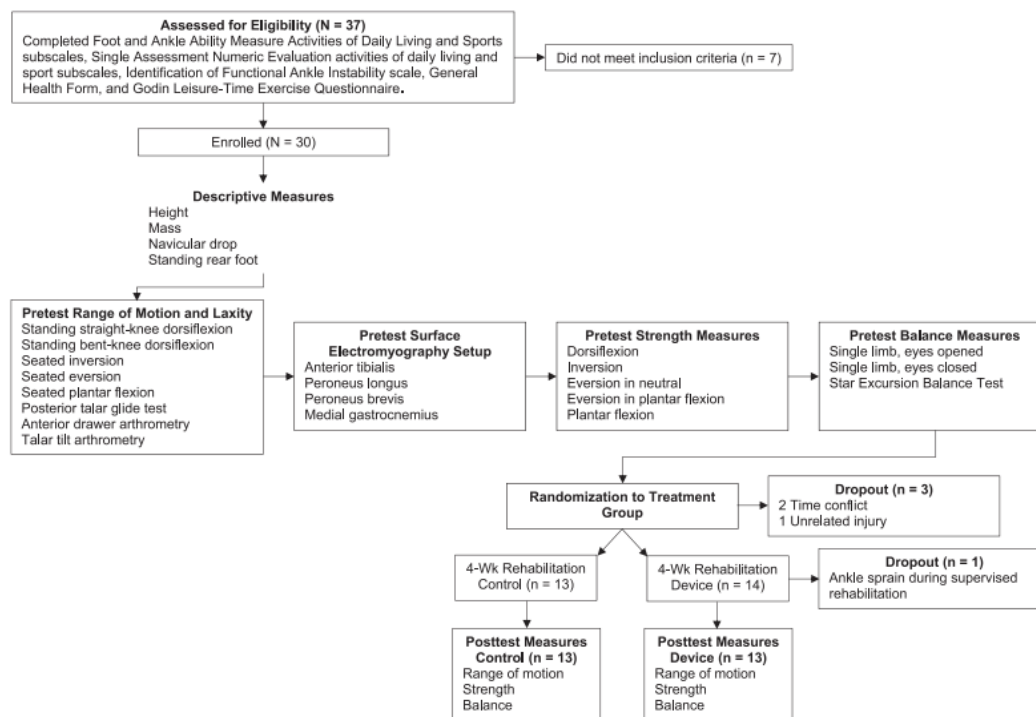


Figure 3. CONSORT flowchart that outlines the methods used for this study.

Figure 3: Details participant progression through study enrollment, group allocation, intervention, and follow-up, displaying how many completed the study and the reasons for exclusions.

Table 2. Participant Baseline Demographics (N = 26; Mean ± SD)^a

Variable	Group	
	No Device (n = 13)	Device (n = 13)
Age, y	21.46 ± 2.88	21.31 ± 3.35
Height, cm	169.11 ± 10.61	168.81 ± 6.89
Mass, kg	75.33 ± 13.70	66.12 ± 12.90
No. of sprains	3.08 ± 1.50	6.15 ± 5.37
Last sprain, mo	24.46 ± 22.51	10.27 ± 9.82
First sprain, y	5.58 ± 3.57	7.92 ± 5.22
Baseline Foot and Ankle Ability Measure Activities of Daily Living scale (range, 0–84)	87.65 ± 7.96	85.76 ± 7.26
Baseline Foot and Ankle Ability Measure Sports scale (range, 0–32)	65.87 ± 18.24	67.07 ± 13.42
Identification of Functional Ankle Instability (range, 0–37)	22.92 ± 1.71	23.23 ± 5.15
Godin Leisure-Time Physical Activity Score (range for this data set, 13–30)	58.77 ± 16.45	79.69 ± 31.66
Standing rear-foot angle, °	5.67 ± 2.93	4.15 ± 0.99
Navicular drop, mm	6.85 ± 3.03	6.85 ± 2.30
Anterior drawer arthrometry, mm	9.37 ± 4.34	11.72 ± 5.15
Inversion arthrometry, °	45.67 ± 9.82	45.07 ± 7.45
Average time per rehabilitation session, min	65.18 ± 4.69	66.25 ± 7.98

^a Indicates no differences between groups at baseline.

Table 2: Presents average age, height, mass, number of prior sprains, ankle measures, initial function scores, and shows no baseline differences between groups.

Table 3. Self-Reported Function Scores for the No-Device and Device Groups (Mean ± SD) and Hedges g Effect Sizes With 95% Confidence Interval

Variable	No-Device Group		Device Group		Time Main Effect P Value	Group Main Effect P Value	Group × Time Interaction P Value	Pooled Prerehabilitation-Postrehabilitation Hedges g Effect Size (95% Confidence Interval) ^a
	Prerehabilitation	Postrehabilitation	Prerehabilitation	Postrehabilitation				
Foot and Ankle Ability Measure Activities of Daily Living scale, %	87.65 ± 7.96	95.60 ± 3.31	85.76 ± 7.26	95.97 ± 4.55	<.001	.69	.46	1.49 (0.88, 2.11)
Foot and Ankle Ability Measure Sports scale, %	65.87 ± 18.24	86.85 ± 11.39	67.07 ± 13.42	85.82 ± 8.33	<.001	.98	.71	1.50 (0.88, 2.11)
Single Assessment Numeric Evaluation Activities of Daily Living score	87.85 ± 11.15	95.08 ± 4.35	83.00 ± 20.49	94.54 ± 8.41	.006	.49	.49	0.74 (0.18, 1.30)
Single Assessment Numeric Evaluation Sport score	72.62 ± 20.89	90.23 ± 8.35	73.77 ± 16.14	89.00 ± 10.54	<.001	.99	.71	1.11 (0.53, 1.70)
Global rating of change score	NA	4.77 ± 1.42	NA	4.46 ± 1.94		.65	NA	NA

Abbreviation: NA, not applicable.

^a Effect sizes were calculated comparing the pooled prerehabilitation means of both groups with the pooled postrehabilitation means of both groups, with a positive effect size denoting an increase in self-reported function after rehabilitation.

Table 3: Displays pre- and post- rehab data for both groups in measures like FAAM (ADLs and Sport), SANE, and global change rating. Reveals large improvements in both groups, with similar post-treatment scores.

Table 4. Range of Motion for the No-Device and Device Groups (Mean ± SD) and Hedges g Effect Sizes With 95% Confidence Intervals

Variable	No-Device Group		Device Group		Time Main Effect P Value	Group Main Effect P Value	Group × Time Interaction P Value	Pooled Prerehabilitation-Postrehabilitation Hedges g Effect Size (95% Confidence Interval) ^a
	Prerehabilitation	Postrehabilitation	Prerehabilitation	Postrehabilitation				
Standing straight-knee dorsiflexion	34.15 ± 10.38	38.31 ± 7.99	42.08 ± 6.98	47.31 ± 6.96	.02	.003	.78	0.51 (-0.05, 1.06)
Standing bent-knee dorsiflexion	38.08 ± 11.12	43.46 ± 10.68	46.38 ± 7.12	51.08 ± 7.38	.001	.03	.81	0.50 (-0.05, 1.05)
Posterior talar glide	9.10 ± 8.71	14.49 ± 9.77	15.41 ± 8.56	17.05 ± 5.08	.02	.14	.21	0.41 (-0.14, 0.96)
Seated plantar flexion	64.00 ± 9.70	67.38 ± 10.65	64.62 ± 7.18	67.85 ± 5.67	.003	.87	.94	0.39 (-0.16, 0.94)
Seated inversion	32.67 ± 10.42	34.69 ± 8.51	36.92 ± 7.43	35.85 ± 8.16	.72	.40	.25	0.05 (-0.49, 0.60)
Seated eversion	14.31 ± 7.45	18.69 ± 6.10	15.92 ± 6.30	16.85 ± 5.89	.11	.95	.29	0.41 (-0.14, 0.96)

^a Effect sizes were calculated comparing the pooled prerehabilitation means of both groups with the pooled postrehabilitation means of both groups, with a positive effect size denoting an increase in range of motion after rehabilitation.

Table 4: Provides RoM improvements pre- and post- intervention for dorsiflexion, inversion, eversion, and plantar flexion, with moderate effect sizes for dorsiflexion measures.

Table 5. Strength Normalized to Mass (N/kg) for the No-Device and Device Groups (Mean ± SD) and Hedges g Effect Sizes With 95% Confidence Intervals

Motion	No-Device Group		Device Group		Time Main Effect P Value	Group Main Effect P Value	Group × Time Interaction P Value	Pooled Prerehabilitation-Postrehabilitation Hedges g Effect Size (95% Confidence Interval) ^a
	Prerehabilitation	Postrehabilitation	Prerehabilitation	Postrehabilitation				
Dorsiflexion	1.62 ± 0.32	1.83 ± 0.37	1.98 ± 0.60	2.42 ± 0.68	<.001	.02	.12	0.57 (0.01, 1.12)
Inversion	1.32 ± 0.28	1.72 ± 0.41	1.49 ± 0.34	1.93 ± 0.46	<.001	.17	.77	1.07 (0.49, 1.65)
Eversion in neutral	1.61 ± 0.44	1.96 ± 0.49	1.68 ± 0.34	2.19 ± 0.48	<.001	.36	.23	0.97 (0.40, 1.55)
Eversion in plantar flexion	1.34 ± 0.32	1.66 ± 0.43	1.48 ± 0.33	1.83 ± 0.44	<.001	.24	.89	0.85 (0.28, 1.42)
Plantar flexion	3.10 ± 0.86	3.48 ± 0.98	3.58 ± 0.85	4.38 ± 1.17	.002	.055	.24	0.57 (0.02, 1.13)

^a Effect sizes were calculated comparing the pooled prerehabilitation means of both groups with the pooled postrehabilitation means of both groups, with a positive effect size denoting an increase in strength after rehabilitation.

Table 5: Compares normalized strength for five ankle motions showing marked improvements for inversion and eversion, moderate gains for dorsiflexion and plantarflexion in both groups.

Table 6. Static and Dynamic Balance for the No-Device and Device Groups (Mean ± SD) and Hedges g Effect Sizes With 95% Confidence Intervals

Task	No-Device Group		Device Group		Time Main Effect P Value	Group Main Effect P Value	Group × Time Interaction P Value	Pooled Prerehabilitation-Postrehabilitation Hedges g Effect Size (95% Confidence Interval) ^a
	Prerehabilitation	Postrehabilitation	Prerehabilitation	Postrehabilitation				
Eyes open								
Single-limb balance area, cm ²	7.23 ± 2.70	5.75 ± 1.78	7.44 ± 2.37	6.85 ± 2.48	.04	.42	.36	-0.44 (-0.99, 0.11)
Single-limb balance velocity, cm/s	4.26 ± 1.26	3.85 ± 0.89	4.51 ± 1.70	4.51 ± 1.44	.38	.35	.39	-0.15 (-0.69, 0.40)
Eyes closed								
Single-limb balance area, cm ²	29.71 ± 10.18	24.36 ± 8.55	26.44 ± 9.63	21.79 ± 5.57	.047	.26	.88	-0.57 (-1.14, -0.01)
Single-limb balance velocity, cm/s	9.96 ± 2.99	8.91 ± 2.41	9.71 ± 2.77	9.08 ± 2.33	.03	.97	.58	-0.32 (-0.88, 0.24)
Star Excursion Balance Test composite score, %	71.65 ± 8.07	76.61 ± 7.42	78.57 ± 6.03	81.60 ± 4.88	.003	.02	.43	0.54 (-0.01, 1.10)

^a Effect sizes were calculated comparing the pooled prerehabilitation means of both groups with the pooled postrehabilitation means of both groups, with a negative effect size denoting an increase in static balance postrehabilitation and a positive effect size denoting an increase in reach distance for the Star Excursion Balance Test.

Table 6: Includes static and dynamic balance metrics from balance tests, showing moderate increases in reach distance and slight improvement in postural control.

Table 7. Surface Electromyography Amplitudes Normalized to Quiet Resting During Maximal Voluntary Isometric Contractions for the No-Device and Device Groups (Mean ± SD) and Hedges g Effect Sizes With 95% Confidence Intervals

Motion	Muscle	No-Device Group		Device Group		Time Main Effect P Value	Group Main Effect P Value	Group × Time Interaction P Value	Pooled Prerehabilitation-Postrehabilitation Hedges g Effect Size (95% Confidence Interval) ^a
		Prerehabilitation	Postrehabilitation	Prerehabilitation	Postrehabilitation				
Dorsiflexion	Anterior tibialis	40.71 ± 24.50	55.28 ± 20.50	52.82 ± 22.27	53.19 ± 13.37	.10	.47	.11	0.36 (-0.19, 0.90)
Inversion	Anterior tibialis	13.17 ± 9.17	27.82 ± 11.69	17.56 ± 14.21	22.87 ± 12.72	.004	.94	.15	0.81 (0.25, 1.38)
Eversion in neutral	Peroneus brevis	36.15 ± 29.70	48.05 ± 30.52	41.04 ± 26.99	58.01 ± 39.50	.03	.51	.68	0.45 (-0.10, 1.00)
	Peroneus longus	28.79 ± 17.77	39.11 ± 19.38	24.62 ± 11.17	47.14 ± 37.27	.006	.80	.28	0.70 (0.14, 1.26)
Eversion in plantar flexion	Peroneus brevis	33.25 ± 30.20	49.11 ± 26.97	42.20 ± 21.69	62.02 ± 40.14	.01	.29	.76	0.58 (0.02, 1.13)
	Peroneus longus	33.03 ± 20.93	42.79 ± 22.95	30.85 ± 14.91	48.92 ± 33.41	.01	.80	.43	0.58 (0.03, 1.13)
Plantar flexion	Medial gastrocnemius	18.48 ± 13.35	19.95 ± 11.74	25.70 ± 10.44	27.41 ± 10.97	.53	.07	.96	0.13 (-0.41, 0.67)

^a Effect sizes were calculated comparing the pooled prerehabilitation means of both groups with the pooled postrehabilitation means of both groups, with a positive effect size denoting an increase in surface electromyography amplitudes during maximal voluntary isometric contractions.

Table 7: Assesses muscle recruitment changes pre- and post- rehab for key ankle stabilizers, revealing notable increases in sEMG amplitudes for strength-related tasks.

Table 8. Surface Electromyography Amplitudes Normalized to Quiet Resting During Static and Dynamic Balance for the No-Device and Device Groups (Mean ± SD) and Hedges g Effect Sizes With 95% Confidence Intervals

Task	Eyes	Muscle	No-Device Group		Device Group		Time Main Effect P Value	Group Main Effect P Value	Group × Time Interaction P Value	Pooled Prerehabilitation-Postrehabilitation Hedges g Effect Size (95% Confidence Interval) ^a	P Value
			Prerehabilitation	Postrehabilitation	Prerehabilitation	Postrehabilitation					
Single limb	Open	Anterior tibialis	9.83 ± 7.18	8.83 ± 6.51	11.79 ± 8.36	8.86 ± 5.81	.16	.69	.49	-0.28 (-0.84, 0.27)	
Single limb	Closed	Anterior tibialis	15.16 ± 8.65	19.93 ± 9.96	22.57 ± 11.60	19.41 ± 8.05	.72	.29	.09	0.06 (-0.49, 0.62)	
Single limb	Open	Peroneus brevis	8.22 ± 6.45	13.55 ± 13.64	7.99 ± 5.16	9.74 ± 4.63	.16	.36	.48	0.42 (-0.14, 0.98)	
Single limb	Closed	Peroneus brevis	19.62 ± 13.06	27.69 ± 18.84	20.37 ± 10.32	17.86 ± 9.60	.42	.28	.13	0.19 (-0.37, 0.74)	
Single limb	Open	Peroneus longus	11.84 ± 4.20	12.06 ± 7.42	10.84 ± 4.27	14.46 ± 12.53	.30	.79	.36	0.25 (-0.31, 0.81)	
Single limb	Closed	Peroneus longus	24.35 ± 11.98	25.04 ± 13.37	17.53 ± 7.40	19.44 ± 11.62	.61	.11	.81	0.11 (-0.44, 0.67)	
Single limb	Open	Medial gastrocnemius	10.08 ± 7.33	7.47 ± 3.36	17.45 ± 8.68	16.32 ± 12.36	.36	.009	.72	-0.19 (-0.75, 0.36)	
Single limb	Closed	Medial gastrocnemius	14.49 ± 9.33	9.18 ± 3.90	23.35 ± 12.07	20.14 ± 16.61	.14	.01	.71	-0.33 (-0.89, 0.22)	
Star Excursion Balance Test composite	Not applicable	Anterior tibialis	5.35 ± 3.14	6.63 ± 4.05	7.84 ± 3.71	7.62 ± 4.28	.35	.22	.19	0.14 (-0.41, 0.68)	
		Peroneus brevis	2.95 ± 2.49	6.15 ± 6.17	5.53 ± 11.46	4.23 ± 6.13	.43	.90	.07	0.13 (-0.42, 0.67)	
		Peroneus longus	3.85 ± 3.18	6.72 ± 10.40	4.88 ± 7.14	3.78 ± 5.21	.55	.69	.19	0.13 (-0.42, 0.67)	
		Medial gastrocnemius	1.28 ± 1.00	1.78 ± 2.13	5.36 ± 10.04	2.56 ± 3.75	.45	.13	.29	-0.20 (-0.75, 0.34)	

^a Effect sizes were calculated comparing the pooled prerehabilitation means of both groups with the pooled postrehabilitation means of both groups, with a positive effect size denoting an increase in surface electromyography amplitudes during single-limb balance and the Star Excursion Balance Test.

Table 8: Reports muscle activation during static and dynamic balance tasks showing minimal change over the intervention.

VOCAB:
(w/definition)

Impairment-Based Progressive Rehab: A therapy model targeting a combination of patient deficits like RoM, strength, balance, and functional activity, assessed and treated in a structured progression.

	<p>Destabilization Device: Specialized footwear (boots or sandals with unstable soles) designed to enhance muscle activity during movement and aid rehabilitation.</p> <p>Surface Electromyography (sEMG): A technique measuring the electrical activity produced by skeletal muscles, used here to assess motor-unit recruitment during rehab exercises.</p>
<p>Cited references to follow up on</p>	<ol style="list-style-type: none"> 1. Denegar, C. R., Hertel, J., & Fonseca, J. (2002). The effect of lateral ankle sprain on dorsiflexion range of motion, posterior talar glide, and joint laxity. <i>Journal of Orthopaedic & Sports Physical Therapy</i>, 32(4), 166–173. 2. Hale, S. A., Hertel, J., & Olmsted-Kramer, L. C. (2007). The effect of a 4-week comprehensive rehabilitation program on postural control and lower extremity function in individuals with chronic ankle instability. <i>Journal of Orthopaedic & Sports Physical Therapy</i>, 37(6), 303–311.
<p>Follow up Questions</p>	<ol style="list-style-type: none"> 1. Do any long-term differences emerge in reinjury rates or functional measures between patients who use destabilizations devices versus those using unstable surfaces after several months? 2. Which individual exercises or program domains (RoM, strength, functional, or balance) most directly contribute to the rapid improvement observed in self-reported function and strength? 3. How could the rehabilitation protocol be adjusted for athletes or individuals with CAI in athletic training settings with fewer resources or less time than clinic-based programs?

Article #11 Notes: Ankle Angle Prediction Using a Footwear Pressure Sensor and a Machine Learning Technique

Article notes should be on separate sheets

Source Title	Ankle Angle Prediction Using a Footwear Pressure Sensor and a Machine Learning Technique
Source citation (APA Format)	Choffin, Z., Jeong, N., Callihan, M., Olmstead, S., Sazonov, E., Thakral, S., Getchell, C., & Lombardi, V. (2021). Ankle angle prediction using a footwear pressure sensor and a machine learning technique. <i>Sensors</i> , 21(11), 3790. https://doi.org/10.3390/s21113790
Original URL	https://www.mdpi.com/1424-8220/21/11/3790
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	Millions of workers experience musculoskeletal injuries each year, with foot and ankle injuries among the most common, often leading to an average of nine days off work. These injuries arise from forces exerted during movements like bending, twisting, and walking which transfer stress through the talocrural (ankle), tibiofemoral (knee), acetabulofemoral (hip), and lumbar (lower back) joints. Abnormal positions amplify this stress—pronation, for example, is linked to increased back pain in females—while orthotics have been shown to reduce such discomfort. Currently, no system continuously monitors workers' movements to detect high-risk postures, and traditional motion capture methods like the Xsens IMU system are costly (over \$7,900). This study explored a lower-cost alternative using footwear equipped with six FSR sensors and a microcontroller to estimate ankle angles. 26 participants performed squats and stoops while synced Xsens IMUs provided reference data. The researchers normalized and filtered pressure readings, timestamped them, and trained a k-nearest neighbors (kNN) machine learning model in MATLAB to predict ankle angles based on pressure patterns. The kNN compared each new pressure reading to the ten more examples from training data and predicted the corresponding angle category. Results showed high accuracy for ground-contact movements (over 89% on average), though performance declined when the foot was airborne. Because the model classified discrete angle ranges rather than

exact values, the authors suggested future work use continuous regression to improve precision. Overall, their low-cost, compact insole system demonstrated strong potential for real-time workplace movement monitoring to prevent musculoskeletal injury.

- Millions of workers suffer from musculoskeletal injuries
 - Foot and ankle injuries are among the most common
 - 9 days off work due to injury
 - Bending, twisting, and walking creates exertion of forces in lower extremities
- Most force is transferred to the talocrural joint (Ankle), tibiofemoral joint (knee), and finally to the acetabulofemoral joint (hip), and lumbar spine (lower back)
- Stress on joints is amplified in abnormal positions
- Pronation (inward facing foot angle) among females is associated with back pain
 - There was less lower back pain to participants who received an orthotic
- There is nothing that monitors employee movement throughout the day and detects high-risk movement
- Joint angle tracking has traditionally been captured through motion capture technology (expensive and not practical)
 - Xsens full body motion capture system (using IMU's) costs over 7900 USD
- Using FSR's could be an alternative to IMU's
- Using a force plate, it is possible to determine ankle angle based on the person's center of mass
- They design a footwear system w/ six FSR's and a microcontroller
- Position that the foot contacts the ground influences pressure
- They used 6 common pressure points
- As force increases linearly resistance curve is logarithmic
- Data from the insole pressure sensors were recorded at a sampling frequency 50 Hz, stored, and post-processed to train the machine learning alg.
- 26 participants (11 male, 15 females; average age ~22.9). 2 insole sizes were used
- Synced the systems (Xens and Insole) by having the subjects raise their heels at the start and end of each trial. (Pulse in FSR heel sensors and Acceleration spike in IMUs)
- Experimental movements
 - Squats: 10 reps and feet remain on the ground
 - Stoops (lunges): 10 reps per leg, plant foot remained on the ground while corresponding leg left the ground (Caused some confusion in the results)
- Data pre-processing:
 - Pressure signals were normalized to a 0-100 relative scale – Each pressure sensor gives a raw electrical reading which isn't comparable between sensors since FSRs have different sensitivities. So, they found a minimum and maximum for each sensor and converted the reading into a percentage of that range.
 - Smoothed with a low pas filter – Sensor readings are noisy, and this keeps slow meaningful changes but removes random fluctuations
 - Time referenced to the microcontroller start time – The microcontroller marks time = 0 when the recording begins, and every pressure sample

	<p>gets a timestamp from that point to stay consistent.</p> <ul style="list-style-type: none"> • They tried multiple classifiers through MATLABs and decided on kNN – They tested several ML models to see which one gave the most accurate predictions (Decision Trees, Neural networks, Discriminant analysis) • kNN (k-nearest neighbors) - Looks at all the pressure data it has seen, when it gets a new set of pressures it finds the k training examples that are most similar to it, it then checks what ankle angles those 10 examples had, then it predicts the new ankle angle as the most common one among those 10. (If this foot pressure pattern looks most like 10 past patterns that corresponded to a 7-degree ankle bend, I'll predict 7 degrees) • All participant data were pooled then split 80% training/20% validation • For each movement type and for each foot considered, they ran the trained kNN on the validation holdout and computed prediction accuracy and confusion matrices (true positive rate, false negative rate) comparing predicted discrete angle class vs. Xsens reference. • The system relies on ground reaction forces so accuracy decreases when the shoe is off the ground (Cannot predict ankle angle when foot is airborne) • They used categorical (discrete) angle prediction, and they suggested a continuous regression model to improve decimal precision in future work – they divided the ankle movement into ranges of angles instead of exact angles. • The footwear pressure sensor + kNN approach is a low-cost compact method that can predict ankle angle during ground-contact movements with high accuracy. • Has potential for workplace biomechanical monitoring to help prevent injury. •
Research Question/Problem / Need	<p>Can a low-cost wearable footwear system using force-sensitive resistors (FSRs) accurately estimate ankle joint angles during movement, providing a practical alternative to expensive motion-capture systems for monitoring and preventing workplace musculoskeletal injuries?</p>

Important Figures

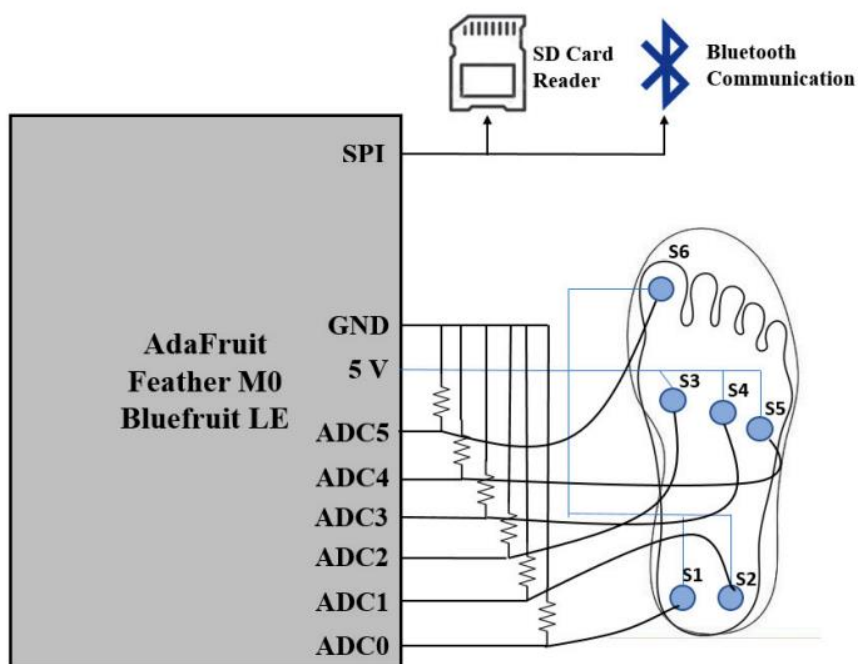


Figure 1. Schematic of the developed pressure sensor system.

Figure 1: There were 6 main pressure points on the bottom of the foot where the FSRs were placed, and this is a roadmap and naming system for the that is referenced throughout the paper.

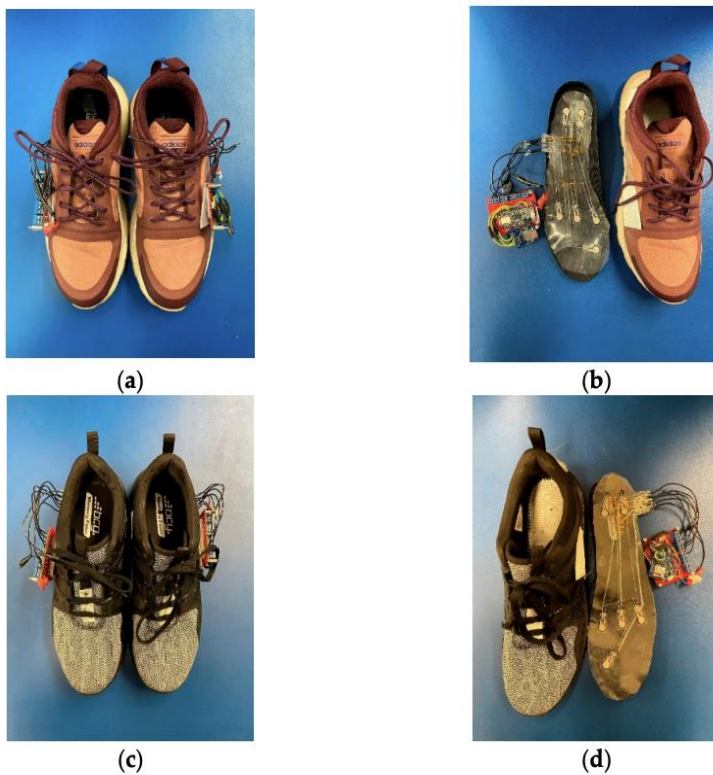


Figure 2. Ankle angle detection system: (a) women's size 8.5 shoes with an integrated microcontroller and data transmission circuit; (b) insole with FSRs and a detection circuit for the women's shoe; (c) man's size 10.5 shoes with an integrated microcontroller and data transmission circuit; (d) insole with FSRs and a detection circuit for the man's shoe.

Figure 2: Real life picture documentation of the device on and off both shoe sizes that were tested in this study.

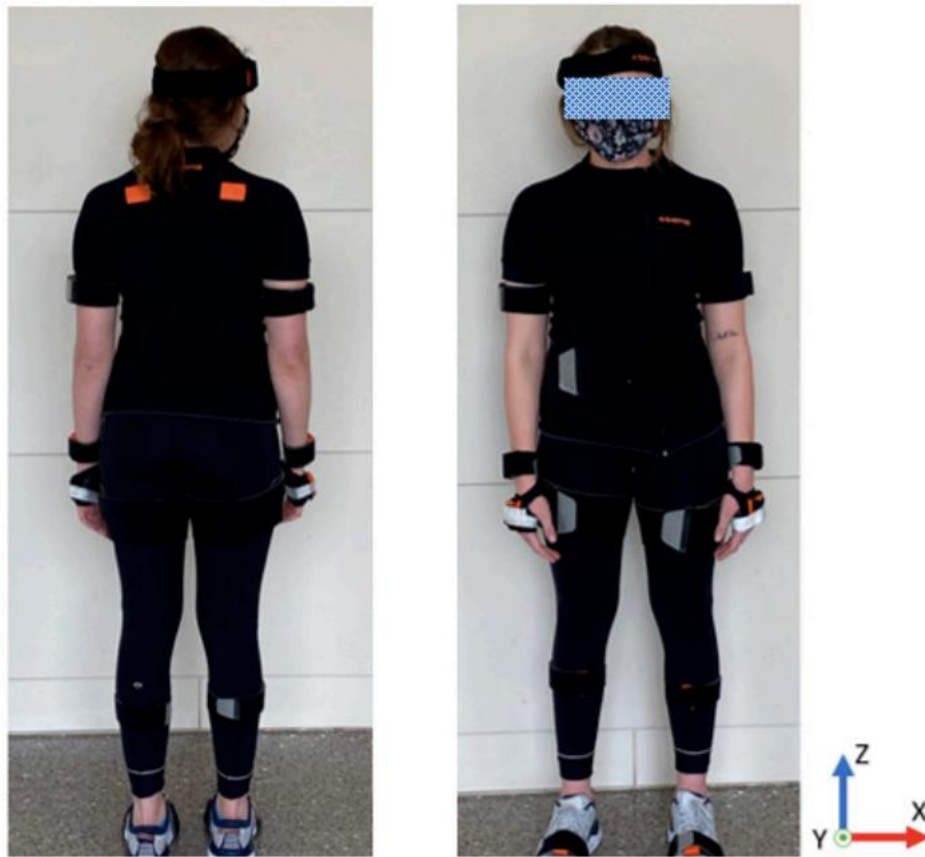


Figure 3. Full Xsens body suit used during testing.

Figure 3: Real life picture documentation of the Xsens bodysuit used to validate the results from the foot-device through syncing the two devices.

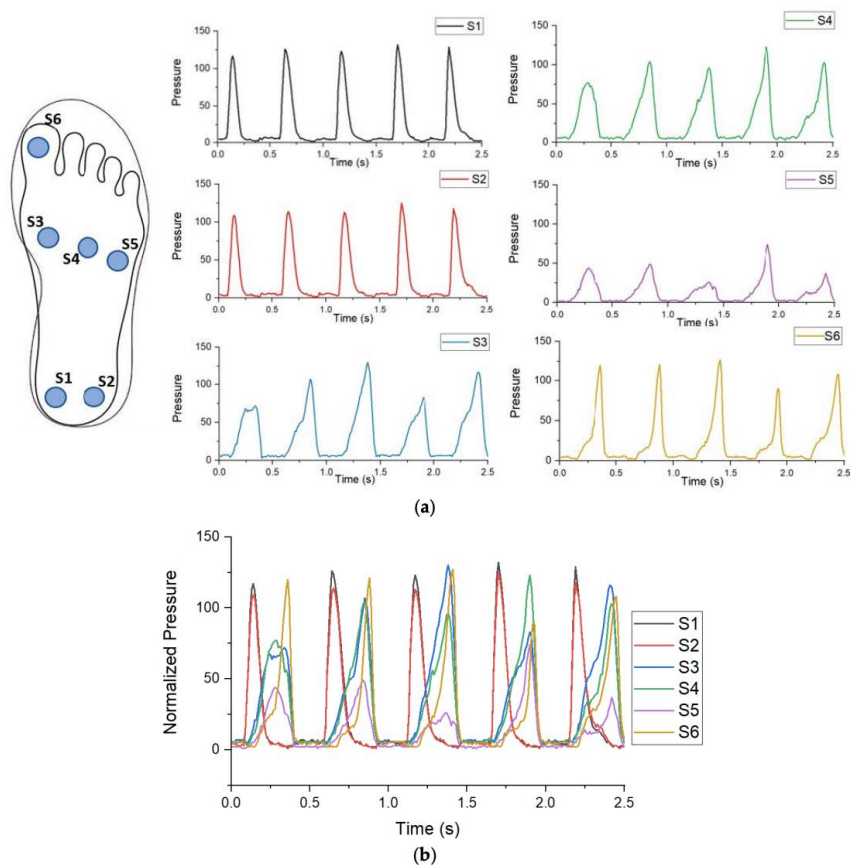


Figure 4. Right foot sensor output for walking; (a) pressure outputs of individual sensors; (b) combined sensor graph with a complete output of the insole.

Figure 4: Pressure outputs of the individual sensors mapped out using the naming system from Figure 1 and then the pressures on one graph for comparison on one graph. This figure validates that the FSRs obtain meaningful pressure data reflecting real foot ground interaction.

to the front of the foot, S3–S6. The squat then ended with S1 and S2 dropping to near zero which signaled the end of the movement.

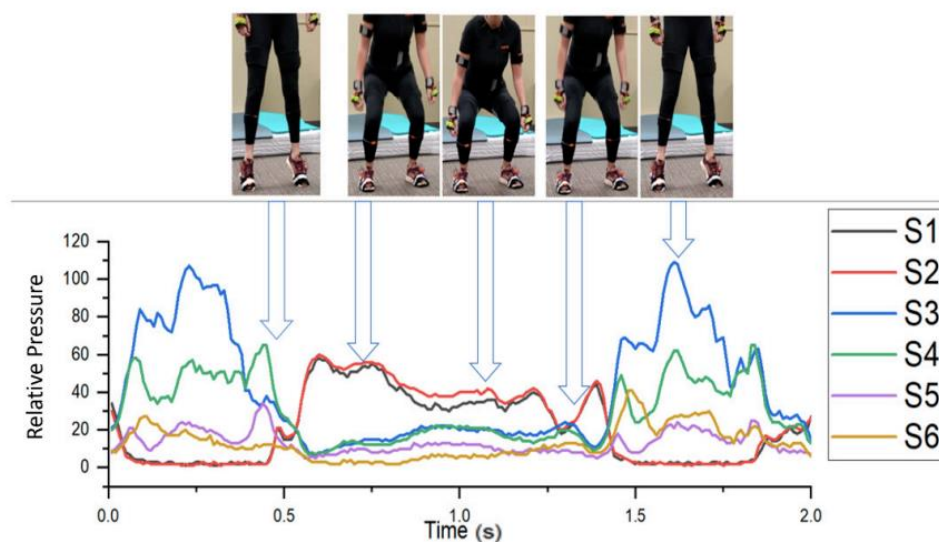


Figure 5. The squat motion with the accompanying sensor readout.

Figure 5: Shows two things for the squat movement:

- A series of diagrams or photos illustrating the phases of the squat performed by a participant
- An aligned plot of pressure data from the foot sensors throughout the movement, demonstrating that as a subject squats, the pressure shifts from the heels (S1 and S2) to the forefoot (S3-S6) and then returns to the heels upon standing. This validates the pressure data's sensitivity to dynamic posture changes.

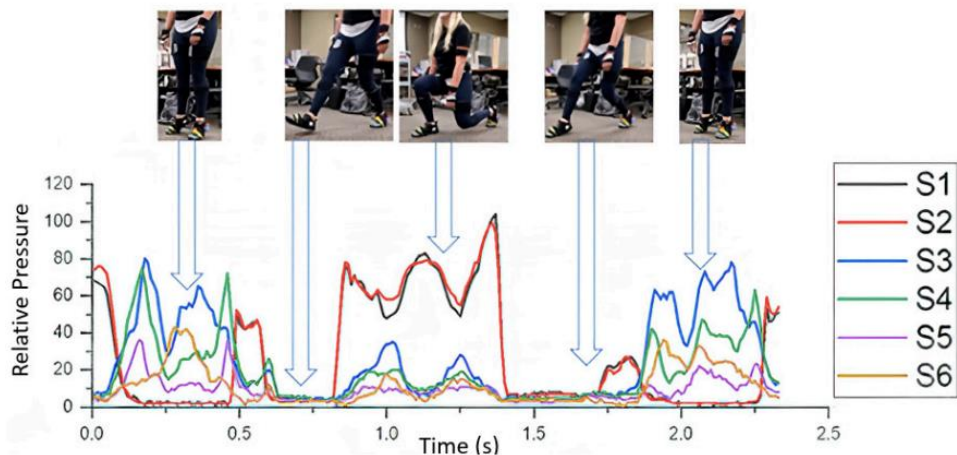


Figure 6. The stoop motion of the experiment with the accompanying sensor readout for the left foot of the movement.

Figure 6: Similar to Figure 5, but for the stoop (lunge) movement:

- Visual sequence or stick figures show the subject's postural changes during a stoop movement

- Plots relate the timing and amplitude of pressure signals (Across six sensors) to stages of the lunge—heel strike, foot lifting off, and forefoot loading

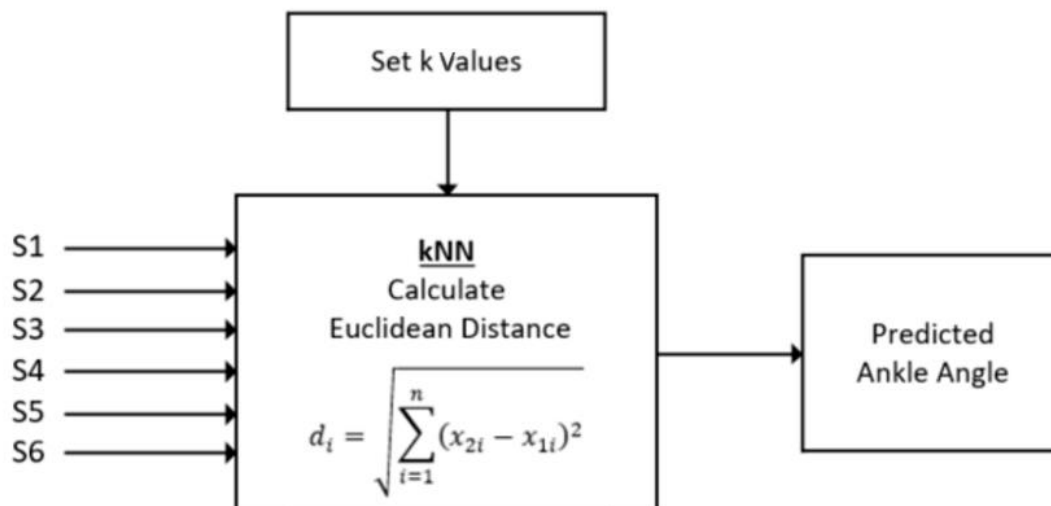


Figure 7. Block diagram of the kNN classification applied to this study.

Figure 7: A flowchart that maps out the kNN machine learning approach used to predict ankle angles:

- Input: The six FSR sensor values
- Process: The kNN algorithm matches input data to known training data (using Euclidean distance) and a=outputs a classified ankle angle bin
- This illustrates the predictive workflow from pressure input to ankle angle output.

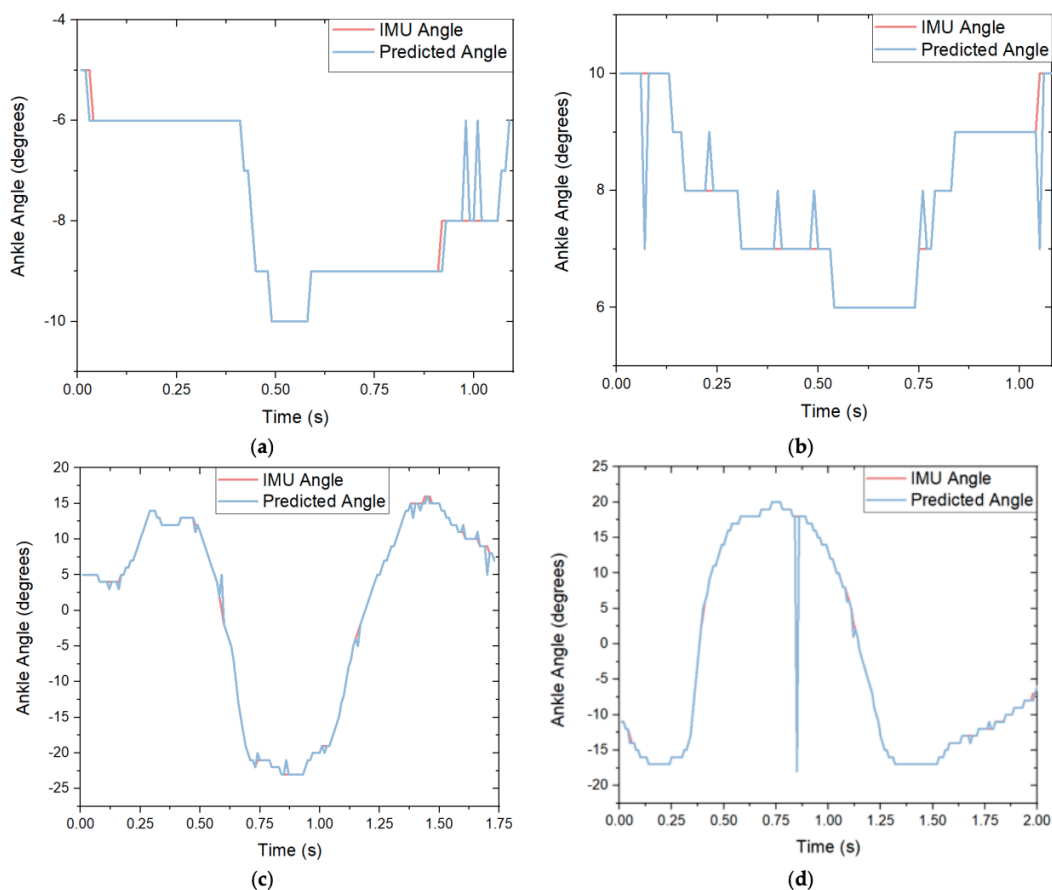
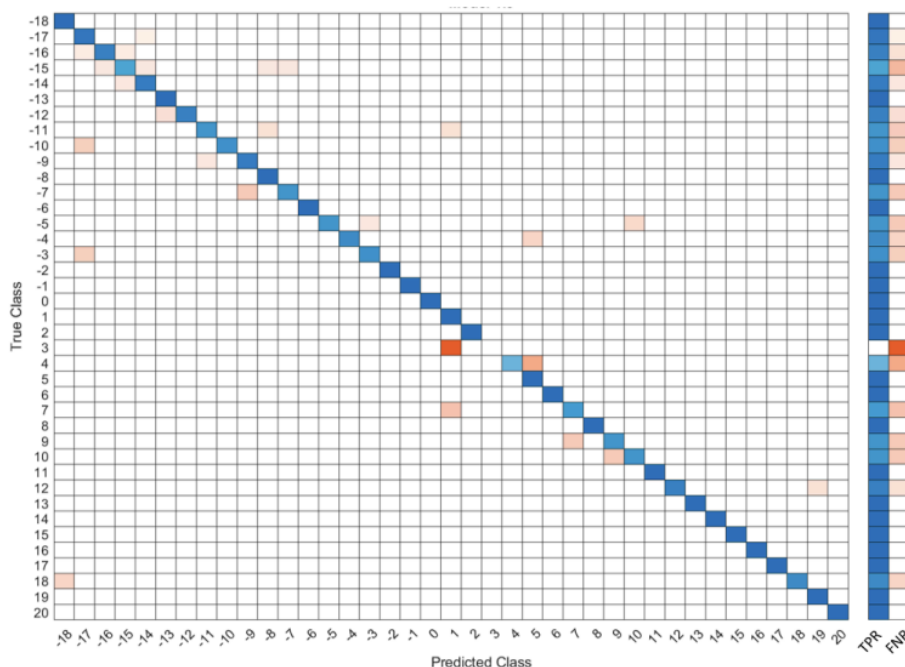


Figure 8. The Xsens-predicted angle compared with the algorithm-predicted ankle angle in the y -axis for each movement: (a) graph of a single squat movement on the left foot with an accuracy of 94.2%; (b) graph of a single squat movement on the right foot with an accuracy of 92.4%; (c) graph of a single right stoop movement on the left foot with an accuracy of 90.2%. (d) graph of a single left stoop movement on the right foot with an accuracy of 88.9%.

Figure 8: Plots comparing the predicted ankle angles (from the ML model) to the actual measured angles (from the Xsens IMU) for different movements and limbs:

- Subplots for left/right squats and stoops
- Each graph shows the close match—with specific accuracy percentages (87-94%) between predicted and reference values—demonstrating the efficacy of the approach in real application scenarios.



(d)

Figure 9. Confusion matrix results for each movement combined size 8.5 and 10.5; (a) squat movement left foot confusion matrix; (b) squat movement right foot confusion matrix; (c) right stoop left foot movement confusion matrix; (d) left stoop right foot movement confusion matrix.

Figure 9: For four movement-coordination pairs (squat left/right foot, stoop left/right foot), this series of confusion matrices presents:

- True angle bins (y-axis) vs predicted bins (x-axis)
- The degree to which the model’s predictions align along the diagonal (perfect prediction), supporting the quantitative accuracy reported in Figure 8.

**VOCAB:
(w/definition)**

Force-Sensing Resistor (FSR): A transducer that changes its resistance based on the force (pressure) applied, used here to measure pressure at different points under the foot.

Inertial Measurement Unit (IMU): An electronic device containing sensors (like accelerometers and gyroscopes) for measuring and reporting a body’s velocity, orientation, and acceleration.

K-Nearest Neighbors (kNN): A simple ML algorithm that predicts the output for a data point based on the majority label (or mean value) of the k-closest points in the training set.

Confusion Matrix: A table used to evaluate the performance of a classification model by comparing predicted results with actual values across all possible categories.

Cited references

1. Winter, D. A. (2009). *Biomechanics and motor control of human movement*

to follow up on	<p>(Vol. 370). Hoboken, NJ: John Wiley & Sons, Inc.</p> <p>2. Pilkar, R. B., Moosbrugger, J. C., Bhatkar, V. V., Schilling, R. J., Storey, C. M., & Robinson, C. J. (2007, August 22–26). <i>A biomechanical model of human ankle angle changes arising from short peri-threshold anterior translations of platform on which a subject stands</i>. In <i>Proceedings of the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society</i> (pp. 4308–4311). Lyon, France: IEEE.</p>
Follow up Questions	<ol style="list-style-type: none"> 1. How does the system perform more complex or real-world movement patterns such as running, jumping, or stair climbing, compared to squat and stoop? 2. Would incorporate more advanced or lightweight machine learning models (neural networks) improve prediction especially for subjects with atypical gait patterns or pathologies? 3. How robust is the insole sensor system to long-term use regarding durability, sensor drift, and the impact of sweat or footwear variation in workplace environments?

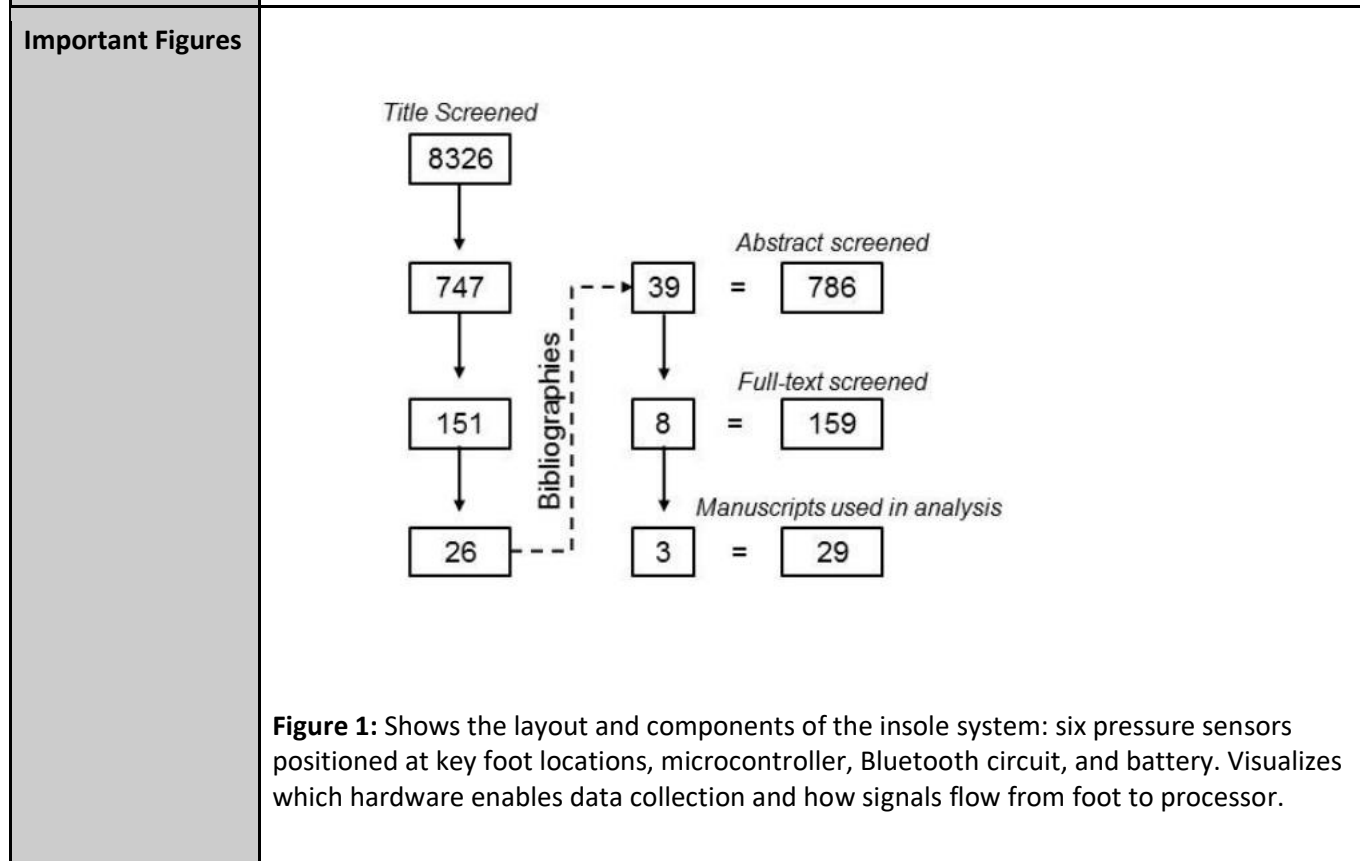
Article #12 Notes: Systematic review and meta-analysis of gait mechanics in young and older adults

Article notes should be on separate sheets

Source Title	Systematic review and meta-analysis of gait mechanics in young and older adults
Source citation (APA Format)	Boyer, K. A., Johnson, R. T., Banks, J. J., Jewell, C., & Hafer, J. F. (2017b). Systematic Review and meta-analysis of gait mechanics in young and older adults. <i>Experimental Gerontology</i> , 95, 63–70. https://doi.org/10.1016/j.exger.2017.05.005
Original URL	https://www.sciencedirect.com/science/article/abs/pii/S0531556516306118?via%3Dihub
Source type	Systematic Literature Review
Keywords	
#Tags	
Summary of key	This paper gives us a systematic review and meta-analysis that examines more than 30

points + notes (include methodology) years of research comparing gait (walking) mechanics between young and older adults. It shows that aging leads to significant alterations in lower limb function: ankle mechanics—especially propulsive power and range of motion—are reduced, and there are moderate changes in hip and knee movements and power. These changes persist even when walking speeds are matched, indicating true age-related effects beyond just slower walking. The findings support the theory that as people age, the lower limb contribution to walking shifts from the ankle to more proximal joints (hip, knee), but compensatory increases at the hip or knee are not always present or consistent across studies. The paper also highlights the large variance in reported studies and urges future research to clarify compensatory mechanisms and the true impact on mobility.

Research Question/Problem/ Need What are the standardized effects of ageing on lower extremity gait mechanics (kinematics, kinetics, ground reaction forces), and to what extent are observed differences in gait patterns between young and older adults attributable to aging versus walking speed?



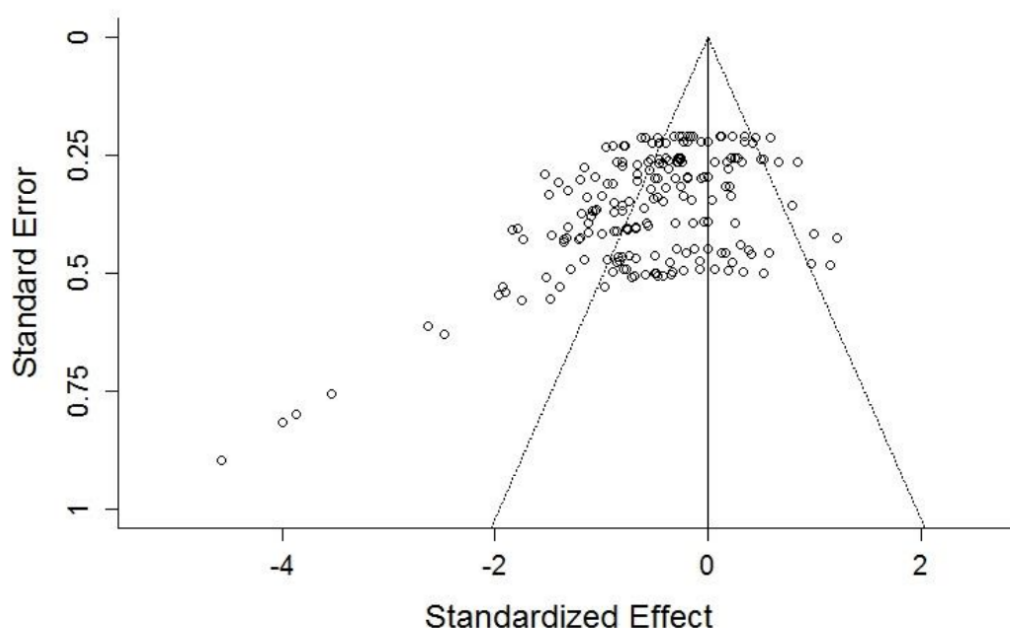


Figure 2: Plots the standard error versus standardized effect for each included study. Ideally, points should be systematically distributed; if not, it may indicate a publication bias in the literature.

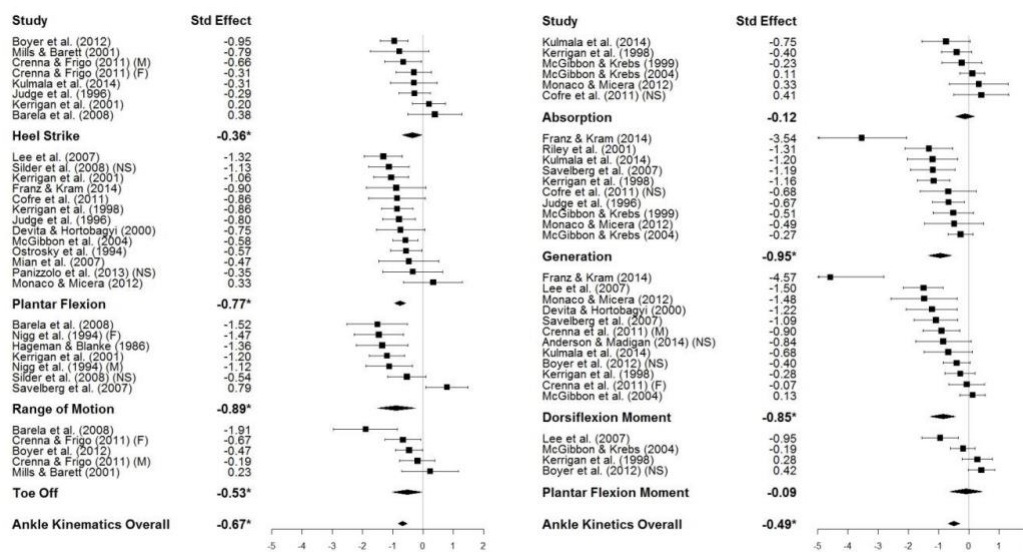


Figure 3: Forest plots displaying standardized effect sizes (with error bars) for individual studies and the overall pooled effects. The left panel (kinematics) demonstrates reduced range of motion and plantar flexion with age; the right (kinetics) shows lower dorsiflexion movements and power federation in older adults.

VOCAB:
(w/definition)

Meta-Analysis: A statistical technique that combines the results of multiple studies to arrive at overall conclusions about a body of literature.

	<p>Kinematics: The study of movement and joint angles, such as RoM and timing, without considering the forces that cause them.</p> <p>Kinetics: The study of forces involved in movement, such as joint moments (torque) and power generation/absorption during gait</p> <p>Ground Reaction Forces: The force exerted by the ground on the body during walking; critical for understanding propulsion and stability during gait.</p>
<p>Cited references to follow up on</p>	<ol style="list-style-type: none"> 1. Silder, A., Heiderscheit, B., & Thelen, D. G. (2008). Active and passive contributions to joint kinetics during walking in older adults. <i>Journal of Biomechanics</i>, 41(7), 1520–1527. 2. Crenna, P., & Frigo, C. (2011). Dynamics of the ankle joint analyzed through moment-angle loops during human walking: Gender and age effects. <i>Human Movement Science</i>, 30(6), 1185–1198.
<p>Follow up Questions</p>	<ol style="list-style-type: none"> 1. What interventions most effectively preserve or restore ankle power and RoM in older adults to counteract the observed age-related decline 2. How do these age-related gait alterations relate to risk factors for falls, everyday mobility limitations, or increased energy expenditure during walking in real-life contexts? 3. Would a finer stratification of “older age” reveal more nuanced differences in gait mechanics or a threshold age at which compensatory changes become prominent?

Article #13 Notes: Dynamics of the ankle joint analyzed through moment-angle loops during human walking: Gender and age effects

Article notes should be on separate sheets

Source Title	Dynamics of the ankle joint analyzed through moment-angle loops during human walking: Gender and age effects
Source citation (APA Format)	Crenna, P., & Frigo, C. (2011). Dynamics of the ankle joint analyzed through moment-angle loops during human walking: Gender and age effects. <i>Human Movement Science</i> , 30(6), 1185–1198. https://doi.org/10.1016/j.humov.2011.02.009
Original URL	https://www.sciencedirect.com/science/article/abs/pii/S016794571100073X?via%3Dihub
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	This study investigated the dynamic properties of the ankle joint during walking by analyzing “moment-angle loops” or plots that describe how ankle joint moments and angles interact throughout the gait cycle in 120 healthy adults divided by age and gender. Four types of loops were identified (Typical, Narrow, Large, Yeilding), with Typical Looks being most common, especially in older participants. The study found only subtle gender and age differences in most ankle joint control parameters: men generally exhibited higher ankle moment, work, and stiffness values that women, and all these measures tended to decline with age, particularly in elderly women. Most importantly, the fundamental biomechanical control strategy for the ankle during walking proved remarkably robust across age and gender, with only minor quantitative adjustments.
Research Question/Problem/ Need	How do age and gender influence the dynamic relationship between ankle joint moments and angles (moment-angle loops) during normal human walking, and what do these effects reveal about the robustness of ankle joint biomechanics and control strategies?

Important Figures

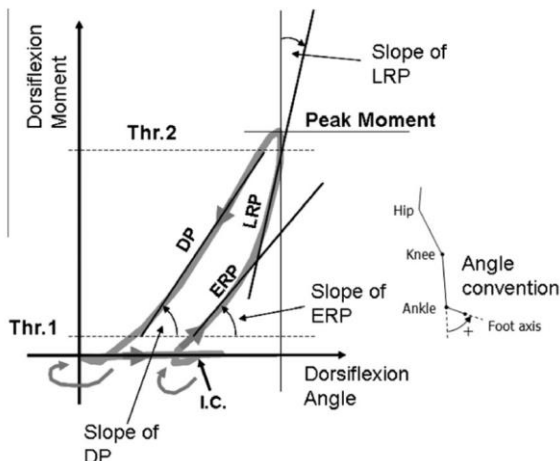


Fig. 1. Descriptive parameters of the moment-angle loops at the ankle joint. ERP = Early Rising Phase; LRP = Late Rising Phase; DP = Descending Phase; I.C. = Initial Contact. The angle convention is depicted on the right. Dorsiflexion moment is to be intended as the moment of the external forces acting on the foot.

Figure 1: This figure shows a representative ankle moment-angle loop with key gait events labeled. The ERP and DP segments have roughly constant slope, representing spring-like behavior while LRP is steep and near-vertical, making the transition between rising and descending limbs.

P. Crenna, C. Frigo / Human Movement Science 30 (2011) 1185–1198 1191

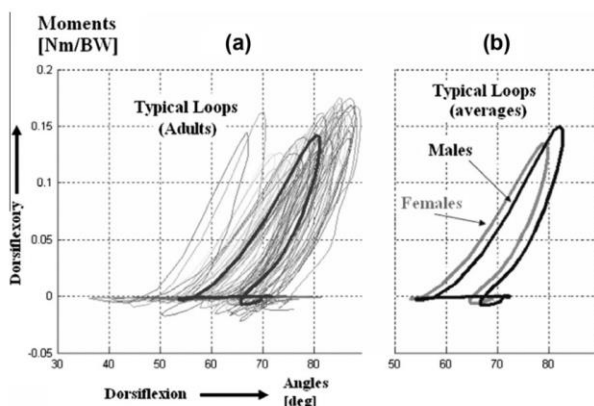


Fig. 3. Typical moment-angle loops obtained in the adults population (N = 53). Each moment-angle loop refers to one subject and was obtained by averaging at least 10 strides performed by the subject with the right and left lower limb. They are represented by grey lines on the left panel (a). The grand average loop is represented as thick solid black line. On the right side (b) the average Typical Loops from the male and female groups are represented superimposed.

Figure 3: Panel (a) overlays all individual “Typical” loops (53 subjects) in thin lines with a thick grand-average loop, showing that most adults share a common loop shape. Panel (b) compares the average loops for adult males and females: female loops are shifted slightly left and have somewhat smaller peak movements.

VOCAB:
(w/definition)

Moment-Angle Loop: A graphical representation plotting joint moment (torque) versus joint angle during a movement cycle, revealing mechanical properties such as stiffness and work done at the joint.

Dynamic Joint Stiffness: The slope of the moment-angle curve during specific gait phases, reflecting how much resistance the joint provides in response to angular displacement.

Work Produced/Absorbed: Mechanical energy generated or taken in by a joint during

	<p>movement, measurable as areas under the moment-angle curve</p> <p>Ergometric Parameters: Quantitative measures describing the mechanical work and power characteristics of joints or muscles during activity.</p>
Cited references to follow up on	<ol style="list-style-type: none"> 1. Kerrigan, D. C., Todd, M. K., & Della Croce, U. (1998). Gender difference in joint biomechanics during walking. Normative study in young adults. <i>American Journal of Physical Medicine and Rehabilitation</i>, 77, 2–7. 2. Savelberg, H. H., & Meijer, K. (2004). The effect of age and joint angle on the proportionality of extensor and flexor strength at the knee joint. <i>Journal of Gerontology A: Biological Science and Medical Science</i>, 59A, 1120–1128.
Follow up Questions	<ol style="list-style-type: none"> 1. How do variations in walking speed or surface affect moment-angle loop characteristics across different age and gender groups? 2. Are the small age-related differences in ankle work and stiffness enough to predict or explain increased fall risk or mobility limitation in the elderly? 3. How do moment-angle loop abnormalities present in populations with clinical conditions such as neurological impairment or joint replacement?

Article #14 Notes: A Multidimensional Assessment of a Novel Adaptive Versus Traditional Passive Ankle Sprain Protection Systems

Article notes should be on separate sheets

Source Title	A Multidimensional Assessment of a Novel Adaptive Versus Traditional Passive Ankle Sprain Protection Systems
Source citation (APA Format)	Willwacher, S., Bruder, A., Robbin, J., Kruppa, J., & Mai, P. (2023). A multidimensional assessment of a novel adaptive versus traditional passive ankle sprain protection systems. <i>The American Journal of Sports Medicine</i> , 51(3), 715–722. https://doi.org/10.1177/03635465221146294

Original URL	https://journals.sagepub.com/doi/10.1177/03635465221146294
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	<p>This paper assesses a novel adaptive ankle brace versus two traditional passive ankle braces (lace-up and rigid) for protection against lateral ankle sprain and user experience in sports. The adaptive brace changes its mechanical properties based on movement intensity, becoming stiffer only in fast, potentially injurious ankle inversion. The study uses biomechanical testing and material simulations with healthy male athletes to compare brace performance across four domains: protection, sports, performance, freedom of movement, and subjective comfort/stability. Results show the adaptive brace offers comparable protection to passive braces during sudden high-velocity inversion, but less restriction and greater comfort during normal movements. It also allows for greater active ankle motion and was rated as less restrictive by users which could improve compliance and use in athletic populations.</p>
Research Question/Problem / Need	<p>Can an adaptive ankle brace that automatically stiffens during rapid, high-risk inversion movements provide sufficient protection against ankle sprain injuries while improving comfort, perceived restriction, and freedom of movement, compared to traditional passive braces?</p>

Important Figures

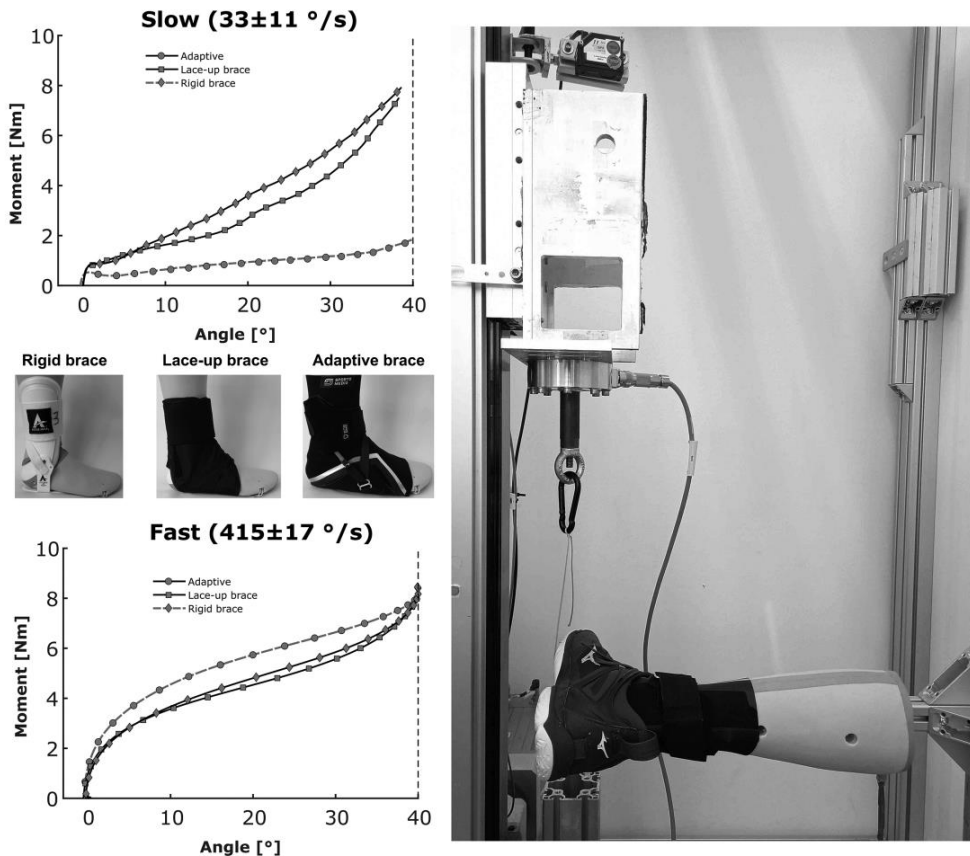


Figure 1. Mechanical tests performed with the artificial ankle (representing the right lower leg and foot) on the different brace conditions. Inversion is induced by pulling the rope connected to the lateral aspect of the foot upward. All braces were tested with the same shoe as during the biomechanical testing. Results represent the mean of 3 trials per condition.

Figure 1: Shows the artificial ankle joint model used for material tests, depicting how the braces (adaptive, lace-up, rigid) are installed, and inversion movements are induced by pulling a rope. Sensors measure joint angle and resist moment, quantifying brace stiffness during slow and fast inversion.

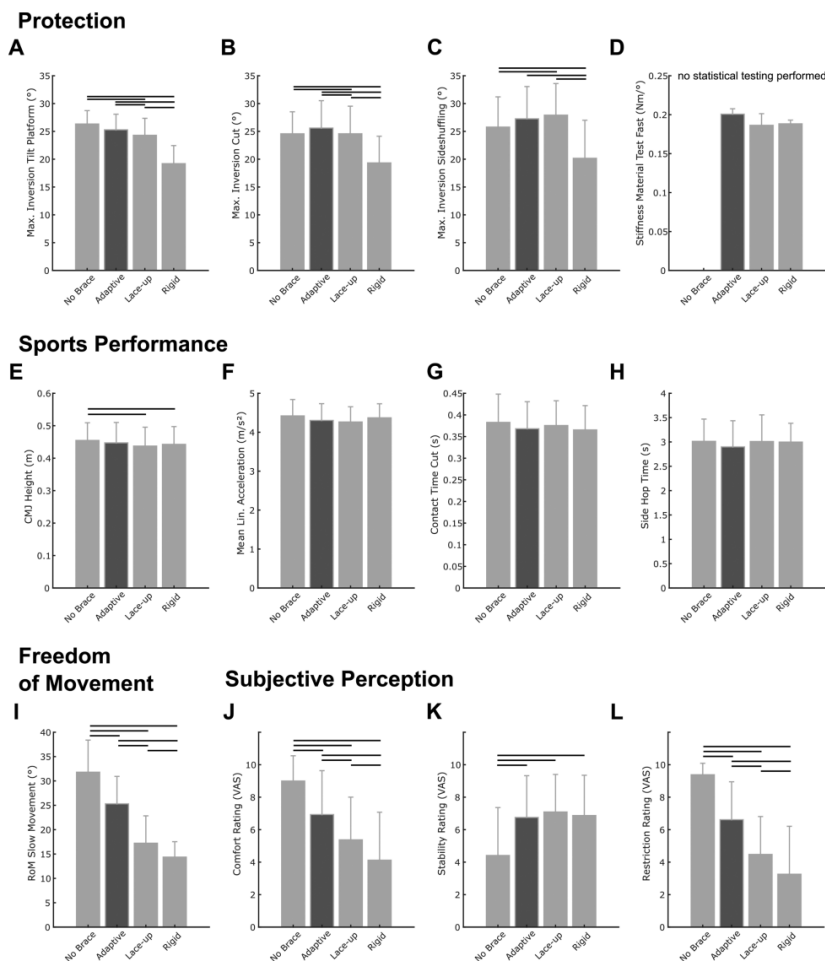


Figure 2. Summary of differences observed for key biomechanical parameters within the 4 domains of ankle sprain protection (A to D: Protection dimension; E to H: Sports performance dimension; I: Freedom of movement dimension; J to L: Subjective Perception dimension). Numeric data of these results are summarized in Appendix Table A1 (available online). Horizontal lines indicate a statistically significant difference between 2 conditions ($P < .05$). Mean Lin., average linear; CMJ, countermovement jump; RoM, range of motion; VAS, visual analog scale.

Figure 2: Multi-panel summary of key outcomes by brace type and test domain

- Panels A-D: Protection dimension, comparisons of peak inversion angle, joint stiffness, and resisting moments under sudden/rapid inversion.
- Panels E-H: Sports performance, vertical jump height, sprint/start acceleration, execution time for change-of direction and side hop test
- Panel I: Freedom of movement, active frontal plane ankle RoM when moving slow speeds
- Panels J-L: Subjective ratings, comfort, perceived restriction, and stability on VAS

Significant differences are highlighted: the adaptive brace consistently allows greater motion, with similar stability, and higher comfort and less restriction than passive braces.

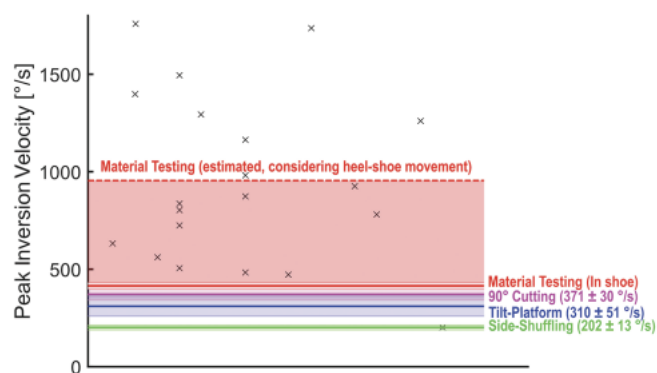


Figure 3. Comparison of peak inversion velocities. Black crosses indicate individual data of ankle injuries that have occurred in either a laboratory or a real game play situation, as summarized by Lysdal et al.¹⁰ Continuous horizontal lines indicate peak inversion velocities measured during the biomechanical and material testing. The colored areas highlight either values of ± 1 SD around the mean values between orthotic conditions (actual mean \pm SD values in parentheses) or the area between the actually measured and estimated peak inversion velocity considering heel-shoe movement in the material testing condition. Because angular velocity measurements during the material testing did not consider the overestimation of rearfoot motion due to marker placement on the heel cap of the shoe, we further estimated a comparable peak inversion velocity for the material testing based on the overestimation factor determined by Reinschmidt et al¹² (factor, 2.3).

Figure 3: Displays measured inversion velocities from both material and biomechanical tests (and compares to injury data from literature), using colored regions and horizontal lines for test conditions. Helps contextualize brace responses in relation to velocities typically observed in real ankle sprain injuries.

VOCAB:
(w/definition)

Adaptive Brace: An ankle brace that automatically alters its mechanical stiffness based on the speed or intensity of ankle movement, becoming protective only when needed.

Passive Brace: An ankle brace with constant mechanical stiffness, providing the same level of restriction regardless of movement speed or injury risk.

Peak Inversion Angle: The maximum inward roll of the ankle reached during testing—a key indicator of injury risk in lateral ankle sprains

Visual Analog Scale (VAS): A subjective measure where participants rate comfort, stability, or restriction on a continuous line, typically 0 (none) to 10 (maximal).

Cited references to follow up on	<ol style="list-style-type: none"> 1. Karlsson J, Peterson L, Andreasson G, Högfors C. The unstable ankle: a combined EMG and biomechanical modeling study. <i>J Appl Biomech.</i> 1992;8(2):129-144. Crossref Web of Science. 2. Rosenbaum D, Kamps N, Bosch K, Thorwesten L, Völker K, Eils E. The influence of external ankle braces on subjective and objective parameters of performance in a sports-related agility course. <i>Knee Surg Sports Traumatol Arthrosc.</i> 2005;13(5):419-425. Crossref PubMed. Web of Science.
Follow up Questions	<ol style="list-style-type: none"> 1. Will similar improvements in comfort and compliance for adaptive braces be seen with athletes who have chronic ankle instability or a history of sprain 2. How do adaptive braces compare to passive braces over longer durations of use, especially regarding wear durability and athlete satisfaction? 3. Can the adaptive brace technology be tuned or customized for different sports or individual athlete preferences without compromising protection?

Article #15 Notes: Brace beats Balance Board: Ankle Sprain prevention; from evidence via practice to the athlete

Article notes should be on separate sheets

Source Title	Brace beats Balance Board: Ankle sprain prevention; from evidence, via practice to the athlete
Source citation (APA Format)	Janssen, K. W. (2016). <i>Brace beats Balance Board: Ankle sprain prevention; from evidence, via practice, to the athlete.</i> [PhD-Thesis - Research and graduation internal, Vrije Universiteit Amsterdam].
Original URL	https://research.vu.nl/en/publications/brace-beats-balance-board-ankle-sprain-prevention-from-evidence-v
Source type	PhD Thesis (Chapter 7: User Survey of three ankle braces in soccer, volleyball and running which brace fits best)
Keywords	
#Tags	
Summary of key points + notes (include	This randomized user survey systematically evaluated the subjective experiences of recreational soccer players, volleyball players, and runners with three commercially

methodology)	available ankle braces: a semi-rigid brace, a lace-up brace, and a compression brace. Participants rated each brace for ease of use, quality, comfort, stability, hindrance, and overall satisfaction after using each during their sport. Results showed all braces scored highly for ease of use and quality overall, but athletes had strong sport- and brace- specific preferences for the other categories. Soccer players and runners favored the compression brace, citing greater comfort, less hindrance, higher satisfaction, and more willingness to buy. Volleyball players strongly preferred the lace-up brace, mainly for perceived stability and satisfaction. These findings highlight that subjective factors, especially comfort and perceived stability, differ by sport and brace type, and strongly influence the likelihood of brace adoption in practice.																																								
Research Question/Problem/ Need	Which ankle brace type, semi-rigid, lace-up, or compression, offers the best user experience in recreational soccer, volleyball, and running as measured by ease of use, quality, comfort, stability, hinderance, satisfaction, and willingness to purchase, and how to preferences differ across sports?																																								
Important Figures	<p>Table 1 Characteristics of athletes per sport.</p> <table border="1" data-bbox="440 831 1317 1121"> <thead> <tr> <th>GROUP (n)</th> <th>All (86)</th> <th>Soccer (29)</th> <th>Volleybal (26)</th> <th>Running (31)</th> </tr> </thead> <tbody> <tr> <td>No of females (%)</td> <td>45 (52)</td> <td>12 (41)</td> <td>16 (62)</td> <td>17 (55)</td> </tr> <tr> <td>Mean (SD) age in years</td> <td>26</td> <td>23 (4)</td> <td>27 (11)</td> <td>28 (12)</td> </tr> <tr> <td>Mean (SD) weight in kg</td> <td>73</td> <td>70 (8)</td> <td>77 (10)</td> <td>73 (13)</td> </tr> <tr> <td>Mean (SD) height in cm</td> <td>180</td> <td>179 (10)</td> <td>182 (9)</td> <td>178 (9)</td> </tr> <tr> <td>Mean (SD) exposure in hours/wk</td> <td>5</td> <td>6 (3)</td> <td>5 (3)</td> <td>*3 (2)</td> </tr> <tr> <td>History of ankle sprain (%)</td> <td>71 (83)</td> <td>26 (90)</td> <td>22 (85)</td> <td>23 (74)</td> </tr> <tr> <td>Experience in ankle brace use (%)</td> <td>25 (29)</td> <td>10 (35)</td> <td>12 (46)</td> <td>*3 (10)</td> </tr> </tbody> </table> <p>*Significant difference compared to other groups (P < 0,05)</p> <p>Table 1: Provides the number of participants, percent female, mean age, body weight, body height, weekly sport exposure, history of ankle sprain, and prior brace use for all athletes and for soccer, volleyball, and running separately. Groups are broadly similar demographically, but runners have lower weekly exposure and less prior brace experience which may influence their ratings and willingness to buy.</p>	GROUP (n)	All (86)	Soccer (29)	Volleybal (26)	Running (31)	No of females (%)	45 (52)	12 (41)	16 (62)	17 (55)	Mean (SD) age in years	26	23 (4)	27 (11)	28 (12)	Mean (SD) weight in kg	73	70 (8)	77 (10)	73 (13)	Mean (SD) height in cm	180	179 (10)	182 (9)	178 (9)	Mean (SD) exposure in hours/wk	5	6 (3)	5 (3)	*3 (2)	History of ankle sprain (%)	71 (83)	26 (90)	22 (85)	23 (74)	Experience in ankle brace use (%)	25 (29)	10 (35)	12 (46)	*3 (10)
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Table 2 Mean scores per brace type (semi-rigid, compression, lace-up) overall and per sport (soccer, volleyball, running) for subjective ease of use, quality, comfort, stability, hindrance and satisfaction. Scores present the mean group value of each construct on a 1 to 5 scale followed by the 95% CI.

Variable	Brace-type	Overall		Soccer		Volleyball		Running	
		Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
Ease of use	semi-rigid	3.9	3.7-4.1	3.8	3.4-4.2	3.9	3.6-4.4	4.0	3.7-4.2
	compression	4.1	3.9-4.3	4.2	3.9-4.5	3.9	3.4-4.4	4.2	3.9-4.4
	lace-up	3.7	3.5-3.8	3.5	3.2-3.9	4.0	3.6-4.3	3.5	3.2-3.8
Quality	semi-rigid	3.6	3.4-3.8	3.5	3.2-3.9	3.7	3.3-4.1	3.5	3.2-3.8
	compression	4.1	3.9-4.3	4.2	4.0-4.5	3.9	3.4-4.4	4.1	3.7-4.4
	lace-up	3.8	3.6-4.0	3.8	3.5-4.0	4.1	3.7-4.5	3.6	3.2-4.0
Comfort	semi-rigid	3.1	2.9-3.4	2.8	2.4-3.3	3.4	3.0-3.8	3.2	2.9-3.5
	compression	4.0	3.8-4.1	4.0	3.8-4.3	4.0	3.6-4.4	3.9	3.6-4.2
	lace-up	3.7	3.5-3.8	3.5	3.2-3.7	3.9	3.6-4.2	3.6	3.3-4.0
Stability	semi-rigid	3.1	2.9-3.4	2.9	2.4-3.5	3.3	2.8-3.7	3.2	2.8-3.6
	compression	3.6	3.4-3.8	3.8	3.4-4.1	3.2	2.7-3.7	3.7	3.5-4.0
	lace-up	4.0	3.8-4.2	3.9	3.7-4.1	4.3	4.0-4.5	3.9	3.5-4.2
Hindrance	semi-rigid	3.0	2.7-3.2	2.8	2.4-3.2	3.2	2.7-3.6	2.9	2.5-3.3
	compression	3.7	3.5-3.9	3.7	3.5-4.0	3.7	3.3-4.1	3.6	3.3-3.9
	lace-up	2.9	2.8-3.1	2.9	2.6-3.2	3.2	3.0-3.4	2.8	2.4-3.2
Satisfaction	semi-rigid	2.7	2.4-2.9	2.5	2.0-2.9	3.0	2.4-3.5	2.6	2.2-3.0
	compression	3.4	3.1-3.6	3.6	3.2-4.0	3.0	2.5-3.5	3.4	3.0-3.8
	lace-up	3.3	3.0-3.5	3.0	2.7-3.4	3.8	3.5-4.2	3.0	2.6-3.5

Table 2: These tables report mean scores and 95% confidence intervals for “ease of use” and “quality” for each brace across all sports. The compression brace scores significantly higher on ease of use than the lace up brace, and its perceived quality score is significantly higher than the semi-rigid brace, confirming it is generally the most user friendly.

VOCAB: (w/definition)

Semi-rigid Brace: An ankle brace with fixed plastic or stiffened components designed to restrict movement and provide high support.

Lace-up Brace: A soft fabric ankle brace fastened with laces that can be adjusted for tightness and provides moderate support

Compression Brace: A fabric brace with stretchable, elastic elements offering light support and compression, often perceived as more comfortable

Likert Scale: A psychometric scale (typically 1-5) used to let survey respondents specify their level of agreement or satisfaction with a statement or product.

Cited references to follow up on

1. Janssen KW, van Mechelen W, Verhagen EALM. The cost-effectiveness of measures to prevent recurrent ankle sprains; results of a three arm randomised controlled trial. Am J Sports Med. 2014;2014 Jul(42(7)):1534-1541.
2. McGuine TA, Hetzel S, Wilson J, Brooks A. The effect of lace-up ankle braces on injury rates in high school football players. Am J

	Sports Med. 2012;40(1):49-57.
Follow up Questions	<ol style="list-style-type: none"> 1. Would these strong subjective preferences and willingness to purchase persist for athletes with clinical history of repeated ankle sprains or chronic instability, rather than healthy recreational players? 2. How might long-term compliance and injury recurrence rates differ if athletes used their preferred ankle brace type for a full competitive season or longer? 3. Are the subjective factors (comfort, perceived stability, hinderance) influential in elite/professional athletes or in sports with different footwork demands?

Article #16 Notes: Do ankle braces affect functional performance? A randomized blinded cross-over trial

Article notes should be on separate sheets

Source Title	Do ankle braces affect functional performance? A randomized blinded cross-over trial
Source citation (APA Format)	Megalaa, T., Le, P. L., Fong Yan, A., Beckenkamp, P. R., & Hiller, C. E. (2024). Do ankle braces affect functional performance? A randomized double-blinded cross-over trial. <i>JSAMS Plus</i> , 4, 100061. https://doi.org/10.1016/j.jsampl.2024.100061
Original URL	https://www.sciencedirect.com/science/article/pii/S2772696724000097
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	This double blinded, randomized crossover trial investigated whether two types of ankle braces, KISS (a soft adaptive brace) and Aircast (a semi-rigid brace), affect functional performance and perceived ankle stability in people with and without chronic ankle instability (CAI) Forty-two participants completed functional tests (jumping, hopping, balance, agility) under three conditions: no brace, KISS, and Aircast. The study found no significant impacts on any functional or balance performance measures, meaning that wearing an ankle brace, soft or rigid, does not impair athletic ability. Subjectively, participants reported significantly greater perceived stability and reassurance when

wearing the KISS brace compared with no brace, while no differences were found for the Aircast brace. The results suggest that braces can be used confidently for protection or reassurance without compromising performance, with soft braces possibly providing additional psychological benefits.

Research Question/Problem/Need

Does wearing an ankle brace, specifically a soft adaptive (KISS) or semi-rigid (Aircast), affect objective functional performance or subjective perceptions of stability, confidence, and reassurance in individuals with and without chronic ankle instability?

Important Figures

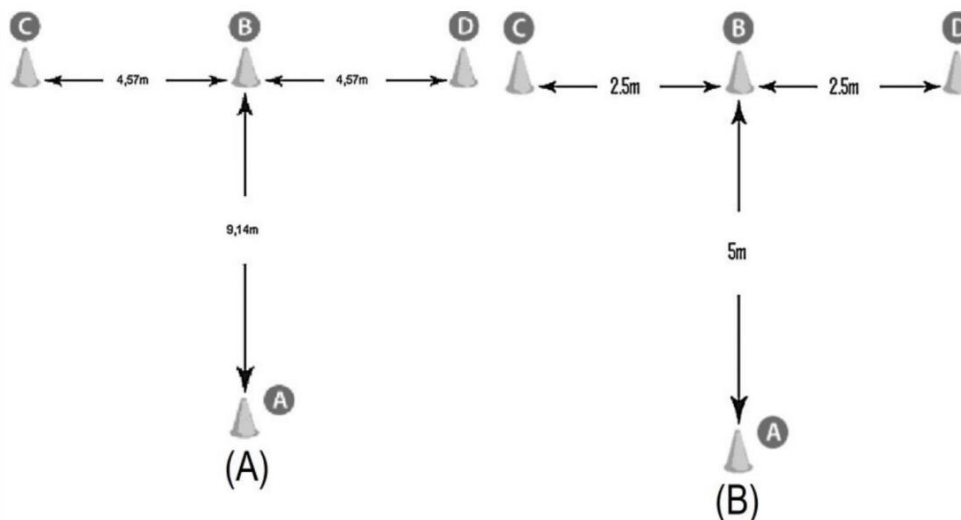


Fig. 1. (A) Agility t-test ten meter distance (B) Agility t-test (modified) five meter distance [27].

Figure 1: This figure depicts the standard T-agility test and modified version used in this study, with cone placements and running paths. It helps interpret the “modified T-agility time” outcome by showing the required forward sprinting, lateral shifting, and backpedaling movements that test change-of-direction performance under each brace condition.

Table 3

Objective measures across the three conditions (KISS ankle brace, Aircast ankle brace and no brace) in uninjured and CAI participants (n = 42), presented as mean \pm standard deviation.

Outcomes	No brace	KISS® ankle brace	Aircast™ A60 ankle brace
Side hop (seconds)	1.26 \pm 0.72	1.28 \pm 0.68	1.30 \pm 0.68
SEBT – anterior direction	67.38 \pm 9.10	67.70 \pm 8.96	67.13 \pm 9.96
SEBT – postero-medial direction	70.53 \pm 15.68	69.26 \pm 14.87	70.08 \pm 14.86
SEBT – postero-lateral direction	78.85 \pm 13.40	78.85 \pm 13.55	79.89 \pm 13.92
Triple hop (cm)	377.24 \pm 98.31	381.66 \pm 98.31	377.21 \pm 88.28
Standing vertical jump (cm)	39.76 \pm 11.78	39.07 \pm 12.12	39.65 \pm 12.41
Maximum vertical jump (cm)	42.66 \pm 14.63	42.58 \pm 15.14	42.26 \pm 14.52
Modified agility T (seconds)	8.78 \pm 1.52	8.96 \pm 1.59	8.99 \pm 1.60

SEBT - Star Excursion Balance Test; cm: centimeter.

Table 3: Reports mean \pm SD for all functional tests in each condition. Values are nearly identical across conditions, supporting the main finding that neither brace alters functional performance compared with no brace.

**VOCAB:
(w/definition)**

Cross-Over Trial: A study design in which participants receive multiple interventions in random order, allowing each participant to serve as their own control.

Star Excursion Balance Test (SEBT): A clinical test of dynamic balance in which participants reach in multiple directions with one foot while balancing on the other.

Perceived Stability: A participant's self-reported feeling of ankle steadiness or security when performing movement tasks, measured using scales like a 10-point numerical rating scale.

Cited references to follow up on

1. Gribble PA, Delahunt E, Bleakley C, Caulfield B, Docherty CL, Fourchet F, et al. Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International Ankle Consortium. *J Orthop Sports Phys Ther* 2013;43(8):585–91
2. Reyburn RJ, Powden CJ. Dynamic balance measures in healthy and chronic ankle instability participants while wearing ankle braces: systematic review with metaanalysis. *J Sport Rehabil* 2021;30(4):660–7.

Follow up Questions

1. Would the KISS brace's benefit on perceived stability translate into measurable reductions in ankle sprain risk during real sport competition over time?

2. How do brace effects differ across sport-specific movements such as running, cutting, or landing under fatigue conditions, particularly in elite athletic populations?
3. Could long-term use of different brace types (soft versus semi-rigid) influence ankle strength, joint mobility, or physiological dependence on external support?

Article #17 Notes: A Wireless Flexible Sensorized Insole for Gait Analysis

Article notes should be on separate sheets

Source Title	A Wireless Flexible Sensorized Insole for Gait Analysis
Source citation (APA Format)	Crea, S., Donati, M., De Rossi, S., Oddo, C., & Vitiello, N. (2014b). A wireless flexible sensorized insole for gait analysis. <i>Sensors</i> , 14(1), 1073–1093. https://doi.org/10.3390/s140101073
Original URL	https://www.mdpi.com/1424-8220/14/1/1073
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	This study details the development of a wireless, flexible pressure-sensitive insole for real time gait analysis, featuring 64 optoelectronic sensors embedded in a silicone matrix to measure plantar pressure distribution without temperature-induced drift or frequent calibrations. The system integrates on-board electronics for high-frequency data acquisition (100 Hz), processing of vertical ground reaction force (vGRF) and center of pressure (CoP), and Bluetooth transmission to a remote GUI for visualization and gait segmentation into stance and swing phases. Experimental characterization validated the sensor's non-linear force to voltage response, while benchmarking against a force platform with healthy subjects walking at varying speeds demonstrated reliable qualitative vGRF profiles, accurate temporal parameters, and potential applications in clinical assessments, sports, and robotic control despite some qualitative errors in force estimation due to uniform calibration.
Research Question/Problem	The engineering goal is to design and validate a low-cost, portable, battery-powered insole system for real time monitoring of plantar pressure during gait, addressing

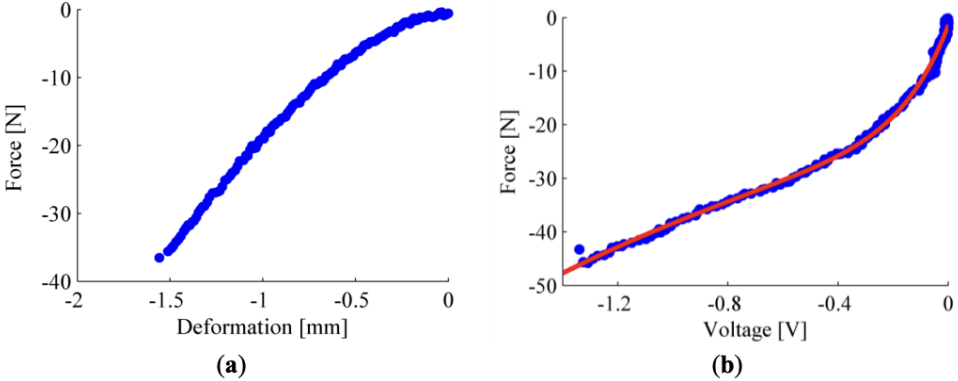
<p>/ Need</p>	<p>limitations of existing technologies like temperature sensitivity, calibration needs, low spatial resolution, and wired setups, while enabling wireless data transmission for applications in gait analysis, pathology assessment, and robotic prosthesis/orthosis control.</p>
<p>Important Figures</p>	<p>Figure 4. Characterization of one representative sensitive element: (a) quasi-static force-to-deformation characterization; (b) quasi-static force-to-output voltage curve, experimental data of one selected sensor (blue dots) and fitting model (solid red line).</p>  <p>Figure 4: Panel (a) is a line graph of force vs. Deformation showing a steep non-linear curve where force increases exponentially with compression. Panel (b) plots force vs. Voltage with blue dots as experimental points and a solid red line as the fitted sum of exponentials. These graphs illustrate the sensor’s mechanical behavior and calibration model, highlighting sensitivity and range.</p>

Figure 6. Extraction of temporal gait parameters. The top and mid panel depict the gait parameters ($vGRF$ and CoP_y respectively) acquired from the right (solid blue line) and left (dotted blue line) pressure-sensitive insole. The bottom panel shows the results of the online classification in gait phases and the use of these phases to calculate temporal gait parameters for the right ($\Delta t_{ST}^R, \Delta t_{SW}^R, \Delta t_{DS}^L$) and left ($\Delta t_{ST}^L, \Delta t_{SW}^L, \Delta t_{DS}^R$) foot.

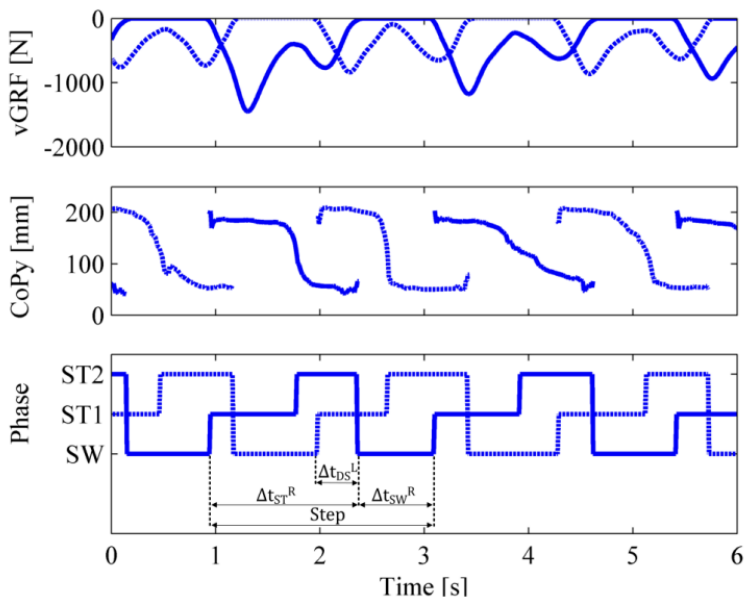


Figure 6: A three-panel time series graph
 Top: vGRF for right and left feet, showing alternating peaks.
 Middle: CoP oscillating between heel and toe
 Bottom: Phase bars with labels for durations.
 This demonstrates how vGRF/Cop data derive parameters like stance/swing times.

Figure 7. Pressure maps under the foot at different gait phases. (a) Weight-acceptance phase of the right foot. The weight is distributed on the heel region. The left foot is swinging; (b) Push-off phase of the right foot. The weight is distributed on the right forefoot. The left foot is starting to contact the ground.

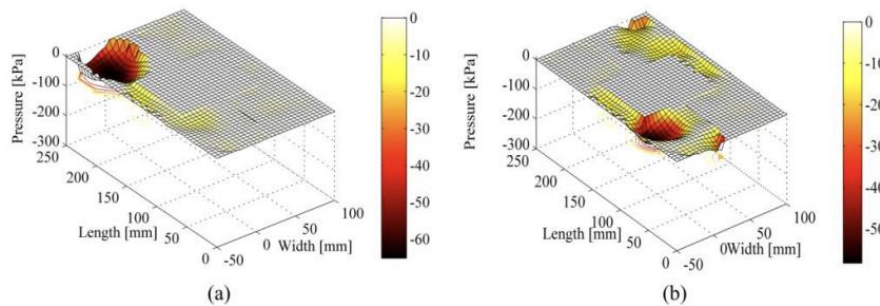


Figure 7: Two 3D mesh plots. (a) Weight-acceptance: peak pressure on heel, forefoot low. (b) Push-off: Peak on forefoot/toes, heel low. These visualize dynamic pressure shifts,

	aiding gait pattern analysis.
VOCAB: (w/definition)	<p>Plantar pressure distribution: The spatial pattern of force exerted on the sole of the foot during activation, measured to analyze gait biomechanics and identify abnormalities.</p> <p>Optoelectronic transduction: A sensing principle where mechanical deformation modulates light between an emitter (LED) and receiver (photodiode) converting force into a voltage signal without amplifiers.</p> <p>Vertical GRF: The upward force from the group opposing body weight during foot contact, typically showing a double-peak profile in gait cycles for assessing loading and propulsion.</p> <p>Gait segmentation: The process of dividing a gait cycle into phases using biomechanical data like vGRF and CoP to extract temporal parameters for analysis or real-time applications</p>
Cited references to follow up on	<ol style="list-style-type: none"> 1. Chang, C.C.; Lee, M.Y.; Wang, S.H. Customized Foot Pressure Redistribution Insole Design Using Image-Based Rapid Pressure Measuring System. In Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, Montreal, Qu, Canada, 7–10 October 2007; pp. 2945–2950 2. Brach, J.S.; Studenski, S.A.; Perera, S.; VanSwearingen, J.M.; Newman, A.B. Gait variability and the risk of incident mobility disability in community-dwelling older adults. <i>J. Gerontol. Ser. A</i> 2007, 62, 983–988.
Follow up Questions	<ol style="list-style-type: none"> 1. How might the insole design be adapted for use in uneven terrain or with populations like amputees, and what impact would that have on sensor durability and accuracy? 2. Could machine learning be integrated into the GUI to improve gait segmentation beyond threshold-based methods, and how would you handle training data variability across users? 3. What are the long-term reliability results for the silicone covers after extended wear, and have you explored alternative materials to further reduce tangential load sensitivity?

Article #18 Notes: The influence of foot positioning on ankle sprains

Article notes should be on separate sheets

Source Title	The influence of foot positioning on ankle sprains
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Source citation (APA Format)	Wright, I. C., Neptune, R. R., van den Bogert, A. J., & Nigg, B. M. (2000). The influence of foot positioning on ankle sprains. <i>Journal of Biomechanics</i> , 33(5), 513–519. https://doi.org/10.1016/s0021-9290(99)00218-3
Original URL	https://www.sciencedirect.com/science/article/abs/pii/S0021929099002183?via%3Dihub
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	This study employs muscle-driven forward dynamics computer simulations to explore how foot positioning at touchdown influences ankle inversion sprain susceptibility during the landing phase of side-shuffle movements, simulating 10 subjects on irregular floor surfaces. By varying subtalar joint and talocrural joint angles at touchdown, the researchers found that increased initial plantar flexion significantly elevates sprain occurrences and severity, defined by exceeding supination angle or passive torque thresholds, due to a larger ground reaction force moment arm about the subtalar joint, while initial supination has negligible impact. These results suggest that impaired proprioception or motor control in previously sprained ankle taping or bracing mitigates this by passively or actively repositioning the foot to a more neutral state before contact, through other factors like ligament damage or muscle strength were not examined.
Research Question/Problem/ Need	How does varying the foot's subtalar and talocrural joint angles at touchdown, affect the susceptibility to ankle inversion sprains in lateral cutting movements, and what implications does this have for understanding chronic instability and the preventative mechanisms of taping or bracing?

Important Figures

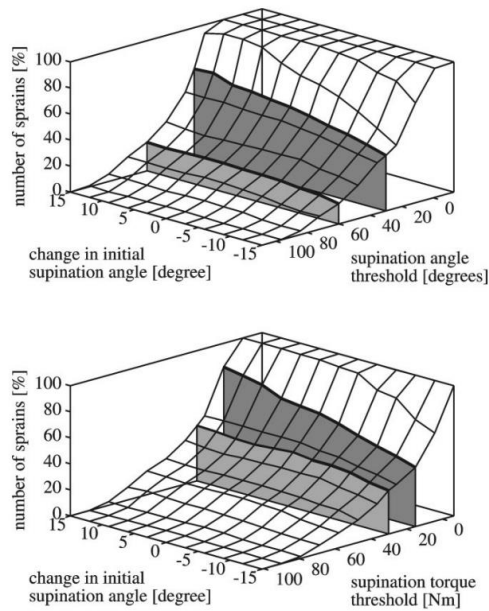


Fig. 3. The number of sprains (percent) as a function of change in initial supination angle and supination angle threshold (top) or supination torque threshold (bottom). Sprains are defined as occurrence of either supination angle (top) or passive supination torque (bottom) exceeding the threshold value. The dark and light shaded supination angle threshold values are 30 and 60°, respectively. The dark and light shaded supination torque threshold values are 15 and 30 Nm, respectively.

Figure 3: Two 3D mesh surface plots. The surface sloped gently upward with increasing initial supination, more steeply at lower thresholds. Dark and light shaded bands highlight 30 degrees and 60 degrees of thresholds. The bottom plot replaces z-axis with supination torque threshold, with shades at 15 and 20 Nm, showing similar trends: slight increase in sprains with more initial supination, but minimal at high thresholds. These graphs demonstrate effect on sprain frequency, often exaggerated at low values due to simulation artifacts.

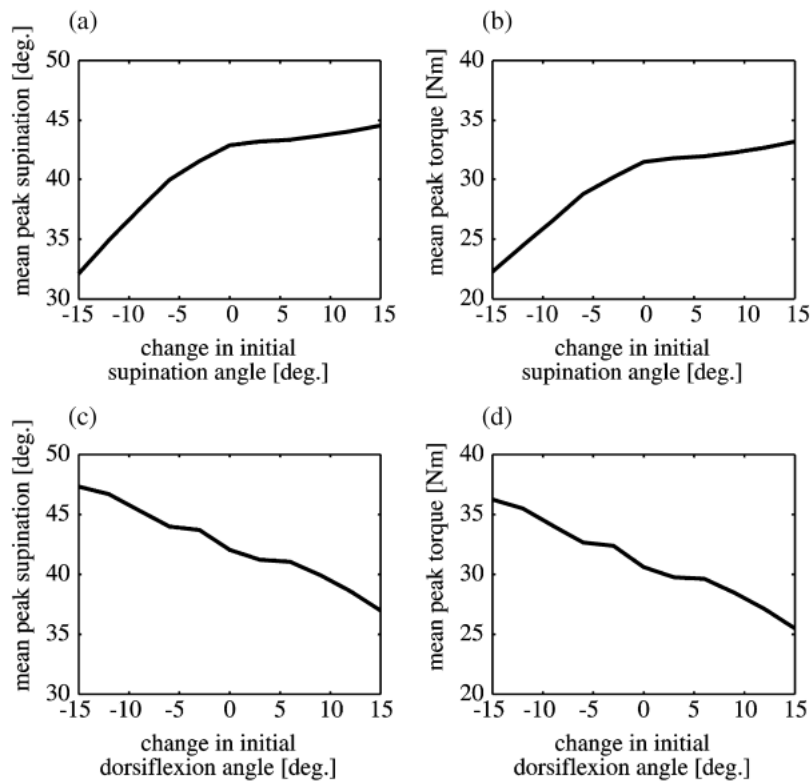


Fig. 5. Mean (across 500 simulations) peak supination angles vs. change in initial supination angle (a), mean peak supination torques vs. change in initial supination angle (b), mean peak supination angles vs. change in initial dorsiflexion angle (c) and mean peak supination torques vs. change in initial dorsiflexion angle (d).

Figure 5: Four 2D line graphs arranged in a 2x2 grid. These plots quantify how initial plantar flexion not only increases sprain frequency but also amplifies peak supination magnitudes, supporting severity implications.

**VOCAB:
(w/definition)**

Inversion sprain: An ankle injury where the foot turns inward excessively (supination), often damaging lateral ligaments like the anterior talofibular (ATF) and calcaneofibular (CF), commonly occurring during sports involving sudden cuts or uneven surfaces.

Subtalar joint: The joint below the ankle that allows inversion/eversion foot movements, crucial for adapting to uneven surfaces and implicated in ankle sprains when excessively supinated.

Pedobarograph: A high-resolution device for measuring foot pressure distribution with spatial detail up to 1 mm, used in gait analysis but limited by lack of portability compared to insoles.

Center of Pressure (CoP): The point where the total vertical ground reaction force acts on the foot sole, tracked spatially during gait to assess balance, propulsion, and

	biomechanical parameters like stance phase transitions.
Cited references to follow up on	<ol style="list-style-type: none"> 1. Isakov, E., Mirzrahi, J., Solzi, P., Susak, Z., Lotem, M., 1986. Response of the peroneal muscles to sudden inversion of the ankle during standing. <i>International Journal of Sport Biomechanics</i> 2, 100}109. 2. Tropp, H., Ekstrand, J., Gillquist, J., 1984. Factors affecting stabilometry recordings of single limb stance. <i>American Journal of Sports Medicine</i> 12, 185}188.
Follow up Questions	<ol style="list-style-type: none"> 1. How would incorporating subject-specific variations in ligament laxity or peroneal muscle response times alter the model's predictions regarding the relative importance of plantar flexion vs. other sprain factors? 2. Could this simulation framework be adapted to evaluate the efficiency of specific ankle brace designs in real-time, perhaps by integrating experimental data from motion capture? 3. What role might footwear properties such as sole stiffness or heel height, play in modulating the effects of touchdown plantar flexion on sprain susceptibility, based on extensions of your model?

Article #19 Notes: Foot Plantar Pressure Measurement System – A Review

Article notes should be on separate sheets

Source Title	Foot Plantar Pressure Measurement System – A Review
Source citation (APA Format)	Abdul Razak, A. H., Zayegh, A., Begg, R. K., & Wahab, Y. (2012). Foot plantar pressure measurement system: A Review. <i>Sensors</i> , 12(7), 9884–9912. https://doi.org/10.3390/s120709884
Original URL	https://www.mdpi.com/1424-8220/12/7/9884
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include	This study reviews existing systems for measuring foot plantar pressure and then proposes a compact wireless in-shoe system based on custom MEMS pressure sensors and a single-chip acquisition (DAQ) and radio. It compares platform and in-shoe



methodology)	<p>systems, details of requirements such as spatial resolution, linearity, hysteresis, sampling rate, and pressure range, and critiques commercial systems and research prototypes. The authors argue that many current systems are limited by bulky electronics, limited pressure range, hysteresis, poor linearity, and power consumption, and propose a low-power CMOS-integrated DAQ IC with MEMS sensors and on-chip antenna to enable fully embedded, wireless plantar pressure monitoring in everyday footwear.</p>
Research Question/Problem/Need	<p>What are the technical requirements, strengths, and limitations of current plantar pressure measurement systems, and how can a new MEMS-based wireless in-shoe system be designed to provide accurate high-range, low hysteresis plantar pressure measurement in a compact, low-power form factor?</p>
Important Figures	<p>Figure 1. A platform-based foot plantar pressure sensor emed[®] by Novel [24].</p>  <p>Figure 2. A platform based foot plantar pressure sensor by Zebris Medical GmbH [25].</p>  <p>Figures 1-2: Shows commercial platform-based pressure mats (Novel emed, Zebris), illustrating rigid floor-embedded arrays that require stepping on a defined area.</p>

Figure 3. An in-shoe based foot plantar pressure sensor by Pedar[®] Novel [24].



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Figure 4. An in-shoe based foot plantar pressure sensor F-Scan[®] System by Tekscan [26].



Figure 3-4: In shoe systems (Novel Pedar, Tekscan F-scan), with flexible insoles and tethered or belt mounted electronics, highlighting benefits (portability, real-world gait) and drawbacks (slippage, lower spatial resolution)

Figure 5. Foot anatomical areas [30].

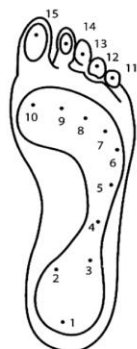


Figure 5: Divides the plantar surface into 15 anatomical areas to guide sensor placement. It motivates design choice of at least 15 sensors per insole so that high-load regions are adequately sampled for gait and pathology studies

Figure 8. Effect of sensor sizing and placement.

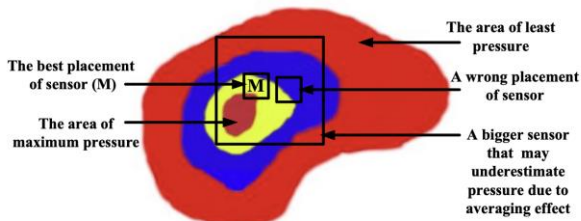


Figure 8: Illustrates how sensor size and misplacement affect peak pressure measurement: too large a sensor averages peaks and wrong placement miss the

	<p>maximum-pressure spot. It visually supports the recommendation for 5x5 mm sensors correctly located in high-pressure regions.</p>
VOCAB: (w/definition)	<p>Plantar pressure: The distribution of pressure under the sole of the foot at the interface between the plantar surface and ground or shoe during standing and locomotion.</p> <p>MEMS pressure sensor: A micro-electromechanical (microscale) pressure transducer fabricated using semi-conductor processes, offering small size, high pressure range, good linearity, and low hysteresis.</p> <p>Hysteresis: The difference between a sensor's output during loading and unloading at the same applied pressure; low hysteresis means nearly identical paths and more accurate, repeatable readings.</p> <p>Wireless DAQ IC: A custom integrated circuit that conditions sensor signals convert them to digital (ADC), modulates and transmits them wirelessly via antenna, acting as a miniature data acquisition and radio unit.</p>
Cited references to follow up on	<ol style="list-style-type: none"> 1. Edgar, S.R.; Swyka, T.; Fulk, G.; Sazonov, E.S. Wearable Shoe-Based Device for Rehabilitation of Stroke Patients. In Proceeding of 2010 Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Buenos Aires, Argentina, 31 August–4 September 2010; pp. 3772–3775. 2. Queen, R.M.; Abbey, A.N.; Wiegerinck, J.I.; Yoder, J.C.; Nunley, J.A. Effect of shoe type on plantar pressure: A gender comparison. <i>Gait Posture</i> 2010, 31, 18–22.
Follow up Questions	<ol style="list-style-type: none"> 1. How does the proposed MEMS + single-chip wireless DAQ system perform in real gait experiments (accuracy, drift, durability) compared with commercial systems like Peder or F-scan? 2. What trade-offs arise when scaling from one sensor to a full 15-sensor insole in terms of power consumption, sampling frequency, and wireless bandwidth? 3. How robust is the on-chip antenna and wireless link in the electrically noisy, body-shadowed environment inside footwear during running or outdoor use?

Article #20 Notes: Multi degrees of freedom Soft Robotic Ankle Foot Orthosis for Gait Assistance and Variable Ankle Support

Article notes should be on separate sheets

Source Title	Multi degrees of freedom Soft Robotic Ankle Foot Orthosis for Gait Assistance and Variable Ankle Support
Source citation (APA Format)	Thalman, C. M., Hertzell, T., Debeurre, M., & Lee, H. (2022). Multi-degrees-of-freedom soft robotic ankle-foot orthosis for gait assistance and variable ankle support. <i>Wearable Technologies</i> , 3. https://doi.org/10.1017/wtc.2022.14
Original URL	https://www.cambridge.org/core/journals/wearable-technologies/article/multidegreesoffreedom-soft-robotic-anklefoot-orthosis-for-gait-assistance-and-variable-ankle-support/C64A9BC0B57316B8DF66D370C70E1FB1
Source type	Journal Article
Keywords	
#Tags	
Summary of key points + notes (include methodology)	<p>This study introduces a soft robotic ankle-foot orthosis (SR-AFO) that uses textile-based pneumatic actuators to provide both push off assistance (plantarflexion) and lateral ankle support during standing and walking, and it rigorously develops and tests the device from modeling through human experiments. The authors first design two actuators, a flat fabric pneumatic artificial muscle (ff-PAM) mounted on the posterior leg to pull the heel up for sagittal-plane plantarflexion, and a multi-material actuator for variable stiffness (MAVS) on the medial/lateral sides of the ankle to increase frontal plane stiffness like an active brace, and fabricate them using layered neoprene, spandex, and nylon integrated into an exosuit worn over athletic shoes. They then build analytical models for both actuators using geometric and energy-based methods for textile pneumatic actuators, predicting how layered alignment affects MAVS stiffness, and validate these models with finite-element simulations and bench tests on a universal testing machine. Finally, in a pilot study with six on/off to quantify changes in lateral ankle stiffness, walking over compliant surfaces with MAVS on/off to measure lateral deflection and treadmill walking with dual ff-PAMs timed to push off to examine ankle kinematics and plantarflexor EMG, showing that activating MAVS increases lateral stiffness and reduces ankle deflection while activating ff-PAMs reduces plantarflexor muscle activity during roughly 40-60% of the gait cycle, all without grossly restricting motion. This end-to-end methodology from actuator modeling and characterization through human testing supports the claim that a lightweight, multi-DOF soft robotic AFO can deliver targeted ankle assistance and variable support and justifies future clinical trials in users with gait impairments.</p>
Research Question/Problem / Need	Can a lightweight fabric based multi-DOF soft robotic AFO using pneumatic actuators can generate sufficient force and stiffness to assist ankle plantarflexion and support inversion/eversion and measurably increase lateral ankle stability and reduce plantarflexor muscle effort during gait in able bodied users, as a step toward

rehabilitative use in impaired populations?

Important Figures

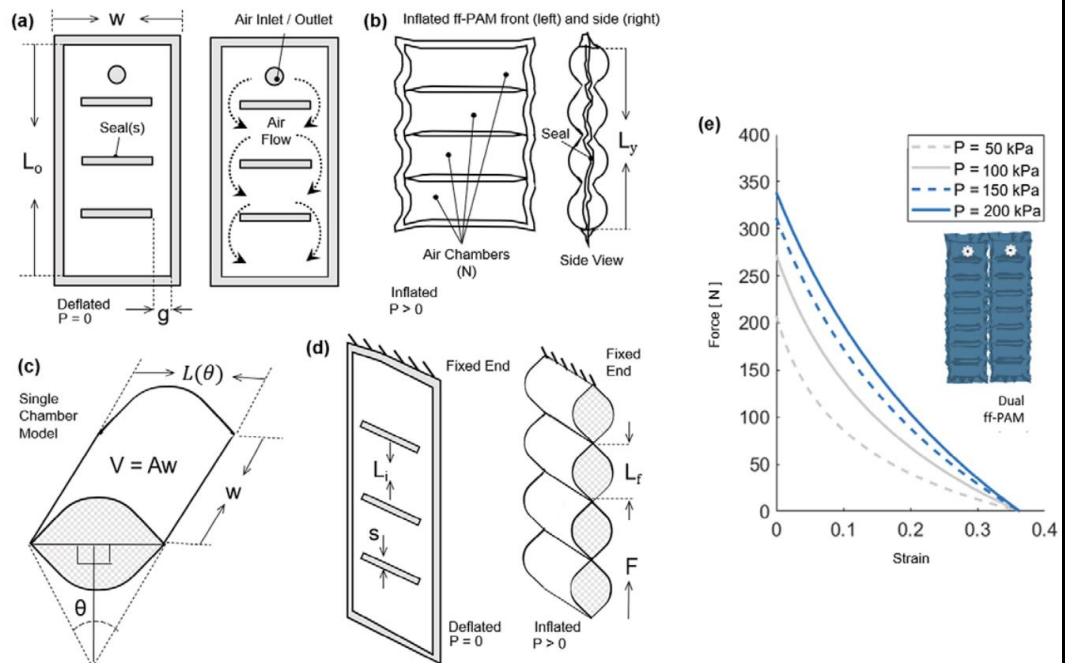


Figure 3. (a) The frontal view representation of the ff-PAM at $P = 0$, which indicates its geometries and the path of airflow within the chambers. (b) The frontal view of the ff-PAM at $P > 0$ where the length and geometries are altered as a result of pressurization. (c) The cross section of a single chamber inspired by previous model iteration of inflatable pouches (Niyama et al., 2015). (d) The isometric view of the ff-PAM in deflated and inflated states, where L_i and L_f are the initial and final lengths of $L(\theta)$, respectively. (e) The theoretical tensile force versus strain curve for the dual ff-PAM actuator, with eight chambers, at pressure levels of $P = 50, 100, 150,$ and 200 kPa resulting from the analytical model. Increasing pressure level result in a more stable and linear response in actuator force profile.

Figure 3: Panels (a-d) use simplified geometries and more detailed drawings to explain how each actuator works: the ff-PAM transitions from a flat strip to a bulged shortened configuration under pressure, pulling its endpoints together and producing joint torque. MAVS behaves like a layered beam whose inflated state increases cross-sectional stiffness, resisting bending in the frontal plane. Deflated versus inflated photos highlight material layers, seams, and the functional change from flexible to supportive.

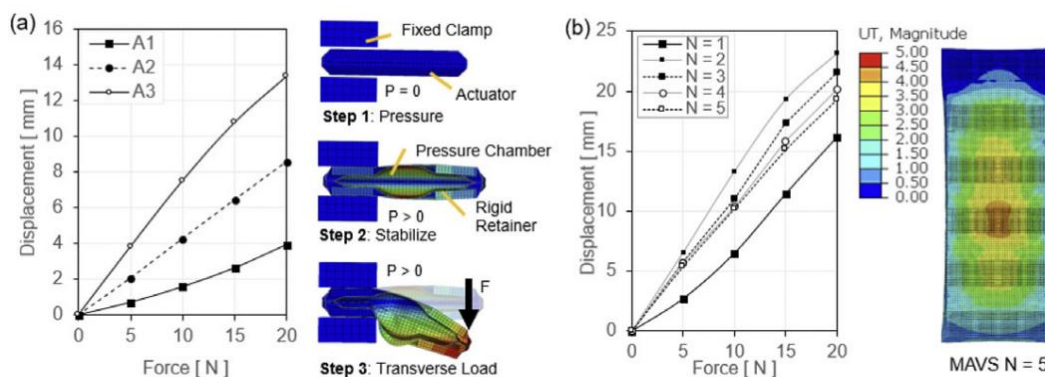


Figure 6. (a) The force–displacement output of a single multi-material actuator for variable stiffness (MAVS) actuator is evaluated with finite element analysis (FEA) for the MAVS-A1, A2, and A3. Various loads are applied to the free end of the MAVS while in a cantilever orientation and the resulting displacement is recorded as the actuator beam begins to buckle under load. (b) FEA simulation results of the same sequence of steps as (a), with the MAVS-A2 actuator, varying the number of segments (N) for each simulation to calculate the total displacement of the free end.

Figure 6: Shows how much the MAVS actuator bends for a given sideways force, proving that pressurized, multi-segment designs can become significantly stiffer and resist buckling, this matters because it demonstrates that the soft brace can actively stiffen the ankle in the frontal plane when needed to prevent lateral “rolling”.

**VOCAB:
(w/definition)**

Flat fabric pneumatic artificial muscle (ff-PAM): A textile-based pneumatic actuator composed of multiple heat-sealed chambers that expand in cross-section and shorten in length when pressurized, generating tensile force along their axis to assist joint motion

Multi-material actuator for variable stiffness (MAVS): A laminate actuator combining soft fabric and stiffer segments arranged so that pressurization changes the alignment/exposure of materials, thereby increasing effective bending stiffness and bracing the ankle against lateral buckling

Push-off phase of gait: The late stance interval (roughly 45-60% of the gait cycle) when ankle plantarflexion generates a large share of propulsive power to move the body forward.

Multi-degree-of-freedom (multi-DOF) assistance: The capability of an orthosis or robot to act in more than one joint plane or axis, more closely matching natural ankle mechanics.

**Cited references
to follow up on**

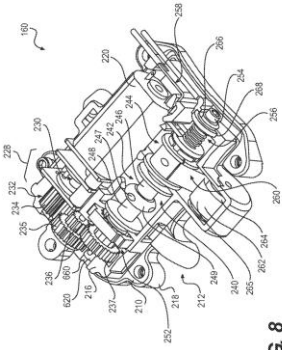
1. Kwon J, Park J-H, Ku S, Jeong Y, Paik N-J and Park Y-L (2019) A soft wearable robotic ankle-foot-orthosis for post-stroke patients. *IEEE Robotics and Automation Letters* 4(3), 2547–2552.
2. Nalam Vand Lee H (2018) Environment-dependent modulation of human ankle stiffness and its implication for the design of lower extremity robots. In 2018 15th International Conference on Ubiquitous Robots (UR). Honolulu, HI, USA: IEEE, pp. 112–118.

Follow up Questions	<ol style="list-style-type: none"> 1. How will the SR-AFO perform in a larger clinical trial with patients who have chronic ankle instability or post stroke hemiparesis, particularly regarding falls, spatiotemporal gait parameters, and long-term adaption? 2. Can the pneumatic supply and control box be miniaturized to support community or home use while maintaining response speed and force output? 3. How does prolonged use affect comfort, skin/interface issues and actuator durability, given the observed ff-PAM seam fatigue and reliance on heat sealed textiles?
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Patent #1 Notes: Motorized tensioning system for medical braces and devices

Article notes should be on separate sheets

Source Title	US9248040B2 – Motorized tensioning system for medical braces and devices
Source citation (APA Format)	Soderberg, M., Capra, J., Henderson, C., Beers, T., Owings, A., & Hipwood, D. (2016). <i>Motorized tensioning system for medical braces and devices</i> (U.S. Patent No. 9,248,040 B2). United States Patent and Trademark Office.
Original URL	https://patents.google.com/patent/US9248040B2/en
Source type	Patent
Keywords	
#Tags	
Summary of key points + notes (include methodology)	<ul style="list-style-type: none"> • The patent introduces a motorized tensioning system designed to tighten and loosen medical braces, footwear, and wearable devices • The system replaces manual tightening (Velcro straps, buckles, hand-pulled laces) with a motor driven spool and lace/cable • It allows for <ul style="list-style-type: none"> ○ Incremental tightening ○ Incremental loosening ○ Full Release • A torque-transmitting mechanism prevents the brace tension from back-driving the motor, improving safety and reliability • The system can automatically maintain prescribed tension, compensating for limb swelling or atrophy over time.

	<ul style="list-style-type: none"> • Control can be done via: <ul style="list-style-type: none"> ○ Physical buttons/knobs ○ Remote devices (smartphones apps, RF controllers) • A motor and gear reduction system drive a spool that winds a tensioning member (lace or cable) • A ratcheting and torque transmitting assembly ensures controlled motion and prevents unintentional loosening • Sensors may monitor tension changes over time. • A control unit: <ul style="list-style-type: none"> ○ Detects when tension drops below a target value ○ Automatically re-tightens the system to restore optimal compression • The system is tested across multiple applications, including: <ul style="list-style-type: none"> ○ Footwear ○ Ankle, knee, wrist, back, and leg braces
Research Question/Problem/Need	<p>How can a medical brace automatically apply, maintain, and adjust tension in a precise and user-friendly way without requiring manual tightening?</p>
Important Figures	<div style="text-align: center;">  <p>FIG. 8</p> </div> <p>Figure 8: Shows the internal components of the motorized tensioning device, including the motor, gear reduction system, spool, and torque transmitting mechanism. It illustrates how the motor rotates the spool to tighten or loosen the tensioning member. This figure is important because it explains the mechanical layout that allows controlled hands-free tightening in medical braces.</p>

	<pre> graph TD 502{HAS USER FINISHED TIGHTENING ARTICLE?} -- NO --> WAIT1[WAIT] WAIT1 --> 502 502 -- YES --> 504[MONITOR TENSION FOR PREDETERMINED INTERVAL TO DETERMINE INITIAL TENSION] 504 --> 506{HAS TENSION DECREASED?} 506 -- NO --> WAIT2[WAIT] WAIT2 --> 506 506 -- YES --> 508[INCREASE TENSION AUTOMATICALLY UNTIL INITIAL TENSION IS ACHIEVED] </pre> <p style="text-align: center;">FIG. 39</p>
<p>VOCAB: (w/definition)</p>	<p>Tensioning Member: A long, flexible component such as a lace, cable, or strap that is tightened or loosened to apply force.</p> <p>Gear Reduction System: A mechanical system that reduces the speed of a motor while increasing its torque.</p> <p>Torque Transmitting System: A mechanism that transfers rotational force from one component to another while controlling direction and motion.</p> <p>Ratcheting Assembly: A mechanical component that allows movement in one direction while preventing movement in the opposite direction.</p>
<p>Cited references to follow up on</p>	<ol style="list-style-type: none"> 1. 5,001,817 A 3, 1991 De Bortoli et al. 2. 3,163,900 A 1/1965 Martin
<p>Follow up Questions</p>	<ol style="list-style-type: none"> 1. How accurately can motorized tensioning systems maintain prescribed compression levels compared to traditional manual braces? 2. What is the impact of automatic tension adjustment on patient healing time and comfort? 3. How can sensor feedback (force, strain, or pressure) be integrated to further optimize brace performance?

Patent #2 Notes: Ankle brace devices, systems, and methods

Article notes should be on separate sheets

Source Title	US11259947 – Ankle brace devices, systems, and methods
Source citation (APA Format)	Owings, A., Beers, T., Henderson, C., Capra, J., & Soderberg, M. (2022). <i>Ankle brace devices, systems and methods</i> (U.S. Patent No. 11,259,947 B2). United States Patent and Trademark Office.
Original URL	https://patents.google.com/patent/US11259947B2/en
Source type	Patent
Keywords	
#Tags	
Summary of key points + notes (include methodology)	This patent describes an ankle brace system designed to provide both support and flexibility for injured or injury-prone ankles. The brace combines internal supports, external supports, ankle pads, and a structured strap system to stabilize the ankle while still allowing natural movement during athletic activity. The design aims to improve comfort, reduce injury risk, and enhance usability compared to traditional rigid or sleeve style ankle braces. The engineers developed a layered support system consisting of a fabric ankle wrap, rigid internal support plates, a bottom stirrup-style support, and external support plates. These components are strategically placed to support the lateral and medial malleolus bones while allowing controlled ankle motion. The brace is secured using a figure-8 strap configuration and heel-lock straps to maintain stability during movement.
Research Question/Problem/Need	<p>How can an ankle brace provide strong joint stabilization while still allowing flexibility, comfort and athletic movement?</p> <p>The engineering goal was to design an anatomically contoured ankle brace that improves inversion and over-extension protection while remaining lightweight, comfortable, and suitable for use during sports or daily activity.</p>

Important Figures

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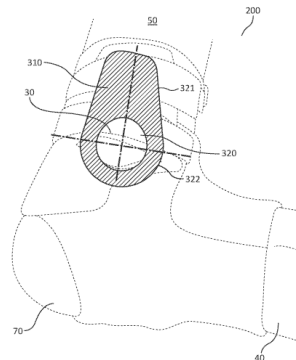


FIG. 4

Figure 4: This figure highlights the internal support plates embedded within the ankle wrap. It shows how the supports are positioned along the sides of the ankle to stabilize the joint. This figure is important because it explains how the brace provides structural support without fully restricting movement.

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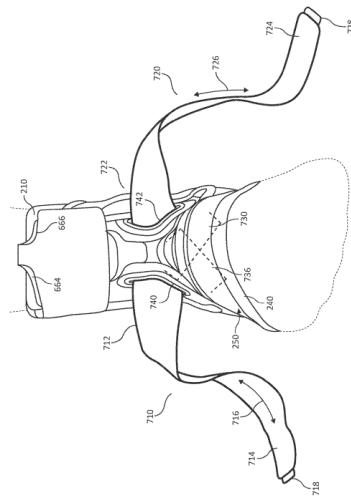


FIG. 14

Figure 14: This figure illustrates the strap system wrapped around the ankle in a figure-8 pattern. It demonstrates how the straps secure the brace and distribute compression evenly. This figure is important because it shows how the brace achieves stability while remaining adjustable and comfortable.

VOCAB: (w/definition)

Malleolus: The bony protrusions on each side of the ankle joint

Internal Support Plate: A rigid or semi-rigid structural component placed inside the brace to provide joint stability.

Stirrup: A supportive structure that extends under the foot and connects both sides of

	<p>the ankle brace.</p> <p>Strap Configuration: A strap pattern that wraps around the ankle in a crossing shape to improve stability.</p>
Cited references to follow up on	<ol style="list-style-type: none">1. 4,523,394 A 6/1985 Lindh et al .2. 5,090,404 A 2/1992 Kallassy
Follow up Questions	<ol style="list-style-type: none">1. How does the figure-8 strap configuration affect ankle stability compared to straight strap designs?2. Which materials provide the best balance between rigidity and flexibility for internal ankle support?3. How does the brace fit and support change during high-impact athletic movement?