WEARABLE TECHNOLOGY IN TRAIL RUNNING

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INTRODUCTION

Trail running involves unpaved paths in mountains, forests, hills, and deserts with uneven terrain, varying elevations, and constantly changing conditions. Terrain, distance and elevation variability provides trail runners with more situations in which to acquire running-related injuries (RRIs), defined as "pain in the lower limbs which prevents individuals from running for seven days and/or three consecutive training sessions" [1,2]. Common RRIs include plantar fasciitis, patellofemoral pain syndrome, and tibial stress fractures [3]. Many variables contribute to RRIs, including kinetics and kinematics, foot strike, and even running shoe selection.

Most biomechanical research on running uses force plates and motion capture systems in a controlled lab setting, which are unable to capture the unique biomechanical demands of the runners on trails. To address gaps in the research, the purpose of this study was to use RunScribe's wearable technology to assess biomechanical differences between injured and non-injured limbs of runners on trails. We hypothesize that the following six biomechanical metrics will be greater in the injured limb compared to the non-injured and healthy control limbs on flat, uphill, and downhill terrain: contact time, shock, impact forces, braking forces, pronation excursion, and maximum pronation velocity.

METHODS

Recruitment

Participants (age: 32.6 ± 9.8 yrs) were recruited through flyers, local running clubs, and social media. Recruited runners were 18-60 years old, ran ≥15 miles/week (at least one trail run), and were either currently uninjured (n=10) or had sustained a RRI 3–12 months prior that disrupted running for ≥1 week or 3 training days (n=8). Exclusion criteria included conditions contraindicating exercise, current pregnancy, or injuries within the past 3 months limiting running for ≥1 week.

Data Collection Procedure

Data was collected at the Cascade Highlands Trail in Bend, OR. Participants were provided Altra Lone Peak 8 shoes, RunScribe pods (placed on the shoes and waistband), and a Garmin Forerunner 255 with a preloaded course map. After a self-paced 10-minute warm-up, pods were calibrated, and participants completed a 2.8-mile run at a self-selected pace. Devices were synchronized before and after each trial.

Statistical Package for the Social Sciences (SPSS) was used to analyze six biomechanical variables: contact time (ms), shock (g), impact (g), braking (g), pronation excursion (°), and max pronation velocity (°/sec). Full run averages, as well as uphill and downhill segments, were analyzed using a linear mixed model with Bonferroni-adjusted comparisons between and within limbs of injured and non-injured runners ($\alpha = .05$).

RESULTS

Pronation Metrics

For downhill pronation velocity, there was a significant difference across limbs ($p = .01$), where pronation velocity was significantly higher in the non-injured limb (1105 ± 45°/s) compared to the injured limb (862 ± 50°/s). There was a trending but non-significant difference in downhill pronation excursion across limbs ($p = 0.11$) when comparing non-injured (13.0 ± 1.5°) to injured limbs (9.0 ± 1.1°). Compared to downhill, the differences between limbs in uphill pronation velocity ($p = .06$), uphill pronation excursion ($p = .14$), full-length run pronation velocity ($p = .08$) and full-length pronation excursion ($p = .17$) were not significant.

Contact Time

There was no significant difference in contact time across all limbs and sections of the run.

Acceleration Metrics

There were no significant differences in braking acceleration, impact acceleration, or shock acceleration across all limbs and sections of the run.

Table 1: RunScribe Biomechanical Metrics

Force Metrics	Section	Limbs				
		Injured Limb	Non – Injured Limb	Healthy Dominant Limb	Healthy Non – Dominant Limb	*p*-value
Pronation Velocity (°/s)						
	Full Length	795 ± 46	945 ± 49	940 ± 75	858 ± 74	0.08
	Downhill	862 ± 50	1105 ± 45	1041 ± 80	961 ± 83	0.01
	Uphill	579 ± 78	721 ± 79	880 ± 149	680 ± 110	0.06
Pronation Excursion (°)						
	Full Length	10.2 ± 0.8	12.2 ± 1.6	11.1 ± 1.6	10.0 ± 0.7	0.17
	Downhill	9.0 ± 1.1	13.0 ± 1.5	11.6 ± 2.1	9.9 ± 11.4	0.11
	Uphill	8.7 ± 1.1	10.4 ± 1.3	9.3 ± 1.3	7.2 ± 0.7	0.14
Braking Acceleration (g)						
	Full Length	9.7 ± 0.5	10.6 ± 0.5	8.7 ± 0.5	8.8 ± 0.6	0.51
	Downhill	8.5 ± 0.6	10.0 ± 0.4	8.7 ± 0.7	8.8 ± 0.6	0.27
	Uphill	9.6 ± 0.9	9.9 ± 0.7	9.2 ± 0.8	8.4 ± 0.7	0.35
Impact Acceleration (g)						
	Full Length	11.3 ± 1.0	11.0 ± 0.5	11.2 ± 0.8	10.7 ± 0.8	0.56
	Downhill	12.0 ± 0.7	11.1 ± 0.7	12.1 ± 0.8	11.1 ± 0.8	0.16
	Uphill	8.7 ± 1.1	9.4 ± 0.4	9.9 ± 1.2	9.1 ± 1.2	0.09
Shock Acceleration (g)						
	Full Length	15.3 ± 0.4	15.6 ± 0.3	14.6 ± 0.4	14.2 ± 0.4	0.54
	Downhill	15.1 ± 0.4	15.3 ± 0.3	15.2 ± 0.5	14.5 ± 0.6	0.37
	Uphill	13.3 ± 1.0	13.9 ± 0.7	13.4 ± 1.1	13.4 ± 1.0	0.46
Contact Time (ms)						
	Full Length	274 ± 9	275 ± 10	290 ± 13	293 ± 13	0.76
	Downhill	260 ± 11	262 ± 12	270 ± 11	271 ± 11	0.59
	Uphill	339 ± 44	340 ± 46	330 ± 36	337 ± 35	0.58

DISCUSSION AND CONCLUSIONS

We found that injured participants demonstrated a faster pronation velocity on their non-injured limb. No other variable had a significant difference between limbs or between-injured/non-injured categories. We hypothesize that this difference is due to injured runners off-loading their injured limb and developing a compensatory gait pattern [4].

Limitations to this study include the relatively short length of the hill used for data selection and the validity of the RunScribe sensors. Additionally, we had a wide variety of running-related injuries within the injured group which made it difficult to draw conclusions specific to particular injuries. Future studies should use longer hills with more elevation change (± 500 feet) to analyze steady-state uphill/downhill running and focus on a specific type of injury to be able to draw additional conclusions.

Overall, these findings largely do not support our hypotheses regarding differences between limbs and warrant further studies to better understand the impacts of running gait deviations on trail runner injury risk.

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PHYSICAL ACTIVITY IN ADAPTIVE SPORTS PROGRAMS FOR NEUROPATHOLOGICAL POPULATIONS

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INTRODUCTION

Physical activity (PA) is defined as bodily movements through skeletal muscle contraction that results in an increased caloric requirement over resting energy expenditure [1]. It has been well established that PA improves quality of life (QOL) measures in most populations [1]. Less than 20% of individuals with acquired neurologic lesions achieve the baseline activity recommendations for adults as defined by the American College of Sports Medicine (ACSM) [2]. Engaging in regular PA decreases morbidity and mortality rates as well as induces disease-modifying effects in this population, and can decrease disability as defined by the International Classification of Functioning, Disability, and Health model [1,2].

There is a wealth of research on the positive effects of PA in non-disabled populations, however, limited research examines these effects in neurologic populations [1-3]. Given that lack of PA in this population is in part attributed to decreased resources, access to adapted sports programming (ASP) might serve as a strategy to achieve ACSM baseline activity recommendations [4]. There is a gap in the literature on effects of ASP on general habits of PA levels and QOL in people with neurologic disability [2,4]. The purpose of this case series was to examine the relationship between participation in adaptive sports programming with changes in PA and QOL in a neuropathic population with physical impairments. It is hypothesized that participation in an adaptive sports program will increase PA and QOL in this population.

METHODS

Participants were recruited from ASP in Oregon via emails and flyers. Participants were included if they were voluntarily participating in 3 sessions of an ASP, have a diagnosed neuropathology, and were a community ambulator or a manual wheelchair user. Participants were contacted prior to their participation in an ASP and were instructed to wear a smartwatch to collect heart rate (HR) and asked to fill out the Short Form-36 (SF-36) and International Physical Activity Questionnaire (IPAQ). Smartwatches were provided if participants did not own their own. One participant engaged in functional testing on OSU-Cascades campus which consisted of the Functional Gait Assessment (FGA), 6 Minute Walk Test (6MWT), and grip strength measurements. Participants were instructed to keep their watches on while they attended three or more sessions of ASP. Following these sessions, participants repeated baseline outcome measures. All participants emailed HR data from their smartwatch to the researchers. Documents with personal identifiers were stored in a protected location. HR data was analyzed on a case-by-case basis comparing activity levels on days with ASP participation to days without participation. Maximum HR was calculated using the Tanaka equation [5]. SF-36 surveys were scored by recoding original scores following the published scoring protocol. IPAQ surveys were scored through converting all minutes reported into metabolic equivalents of tasks (METs).

RESULTS

Participant Demographics: Three participants completed this study: 01M, 03F, 04M. All three participants completed the IPAQ and SF-36, 04M completed functional testing.

HR Results: Activity levels for 01M and 04M were analyzed. 01M's average activity was greater on days with ASP participation (70 min/day) compared to days without participation (6 min/day). 04M's activity was more similar between days with ASP participation (15 min/day) and those without participation (12 min/day) [6].

Surveys: The difference from the pre- and post-ASP SF-36 surveys were calculated and all changes were above minimum clinically important difference (MCID) score. On the IPAQ, participants increased their METs-min/week and 03F moved from the "Moderate" to "High" activity category [6].

Functional Testing: 04M's pre- to post-ASP FGA score increased by the minimum detectable change (MDC). The 6MWT pre- to post-ASP change did not meet the MCID. The average of two trials of grip strength tests decreased by greater than the MCID [6].

DISCUSSION AND CONCLUSIONS

The intention of the study design was to collect HR data prior to the start of adaptive sports programming, followed by tracking HR during activity. HR data prior to activity was not collected for all participants. Increased availability of researchers to ensure adequate timeline of smartwatch coordination would improve this measure moving forward. Further, due to the timeline of this study, it is not possible to determine if activity levels will change long term after participation in programming. Also, heterogeneity of participant diagnosis may result in inconsistent HR responses to physical activity. Given the data we do have, it is reasonable to conclude that access to adapted sports resources put participants at a higher rate of overall activity and greater QOL as measured through meaningful change in MDC on SF-36 scores. This study captured information from a neurologic population that was already planning on participating in adapted sports programming and perhaps already had more resources at baseline to overcome barriers compared to the general population of individuals with neurologic disability. More research is needed to determine the influence of barriers specific to this population on participants' capacity to engage in guided programming, doing an activity on their own, or not doing an activity at all. Future research that recruits participants with diverse access to resources may better reflect the true impact of adapted sports programming on activity levels and QOL in this population.

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PHYSICAL ACTIVITY IN ADAPTIVE SPORTS PROGRAMS FOR NEUROPATHOLOGICAL POPULATIONS: A QUALITATIVE STUDY

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INTRODUCTION

In 2022, more than one in four Oregon adults identified as having a disability [1]. This group often reports lower physical activity levels and poorer health outcomes than those without disabilities [2]. Adaptive sport is defined as sport, with specialized equipment or adapted rules, allowing for anyone with disabilities to take part and compete. Neurologic diagnoses encompassed a variety of impairments, often including mobility disability. 10.2% of Oregon adults claimed a mobility disability [1]. Adaptive sport is uniquely equipped to address the neurologic populations' mobility and shield them from the negative impacts of low physical activity and poor health outcomes [3]. Understanding the lived experience aids in providing proper interventions and systems to support the wellbeing of a specific population. The limited literature on the impact of adaptive sports on neuropathic populations, suggest that their perspective is yet to be explored. The phenomenology type of qualitative research allows us to identify the personal perspectives and holistic factors within the adapted athlete's experience, distinguish themes and discover connections between individuals' experiences and interventions [4].

The purpose of this study was to describe the lived experiences of adaptive athletes within the neuropathic population.

METHODS

The research team used purposive sampling approach and recruited five adaptive athletes (four male, one female, 42–68 years) all with acquired neuropathic conditions. The inclusion criteria was: participation in an adaptive sports program, diagnosed neuropathology causing physical limitations, ability to cross intersections with or without assistive devices and planned to complete three adaptive sport sessions. Participants completed individual, recorded semi-structured interviews after providing consent. Transcripts were professionally transcribed and managed using data software. Two researchers independently coded the data, cross-checked for agreement, with discrepancies resolved by a third researcher and then uploaded to the software for grouping. The research team then analyzed the compiled codes to identify themes and sub-themes.

RESULTS

Three main themes where identified, health, access, and community, detailed by 12 sub-themes (Figure 1). The theme of Health is identified as the individual factors that impact the athlete's physical, mental and social well-being.

The sub-themes provided insight into the factors contributing to overall health of an Adaptive Athlete: The experience must be salient to each individual and contribute to their quality of life, requiring resilience from the athlete and following a unique timeline to participation that varies with each sport and individual recovery journey.

> *"...doing sports was important to me, my mental health and my wellbeing...fundamentally that's who I am." (Participant 3)*

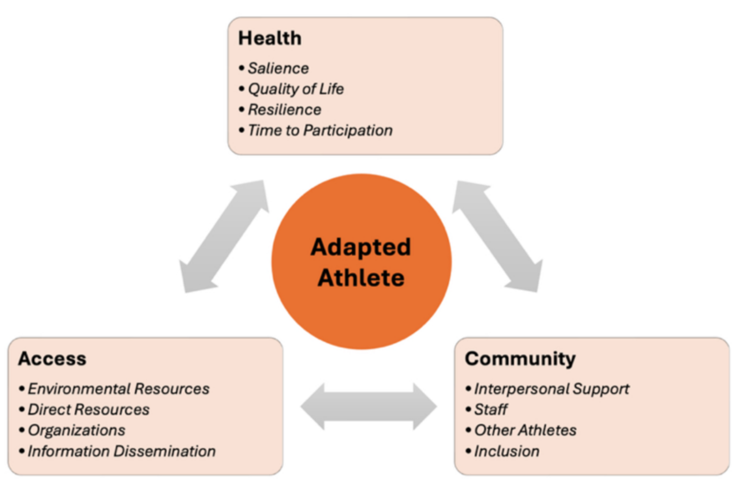

Figure 1: Visual representation of themes and sub-themes

The theme of Community, defined as: the personal support within the athlete's social circle. The community built within adaptive sports and recreation can impact the athlete's mental and physical health, because athletes are surrounded by individuals with shared experiences

> *"...It's great to meet other folks with similar disabilities or other situations that have been through similar either traumatic experiences or just other experiences. It's almost like a support group and a brotherhood or family that you create from those experiences." (Participant #2)*

Having a strong community is crucial to the physical and social engagement in adaptive sports and recreation because it encourages more participation from athletes.

> *"...we interact with each other …it's a way of developing not just that community of being handicapped, but developing a friendship with those folks, not only with the volunteers who are helping you stay out of trouble, but with the other athletes as well." (Participant #1)*

Community requires the interpersonal support for each individual athlete, the staff of the program, other athletes within the program, and a sense of inclusion felt by the individual adaptive athlete. The theme of Access is identified as, factors within the athlete's environment, health care, or socioeconomic status affecting participation.

> *"After a couple of years, I got a grant to buy a hand cycle...but it wasn't the right fit for me. I couldn't use it, eventually sold it. So having the fleet that [organization] has, of so many different sizes and shapes of equipment...it's really huge…." (Participant #5)*

An athlete's ability to participate is reliant upon access to physical resources, organizational support, immediate resources, and information dissemination.

> *"There really isn't any institutional outreach on the part of [Adaptive sports program] or [Physical therapy clinic] ... I mean, it would be a great place for a person to work in that space that's in between the patient, the client, and the organization. There's a gap in between." (Participant #4)*

DISCUSSION AND CONCLUSIONS

The findings of this study provided further insight about the lived experiences of individuals who participate in adaptive sports. The themes identified in this study align with previous adaptive sports qualitative research [5]. The participants discussed how adaptive sports allowed them to live an active lifestyle and provided a community of individuals similar to themselves. Additionally, they discussed how access to financial and physical resources could greatly impact one's experience in adaptive sports, as adaptive equipment and lessons tend to be more costly and less available. A lack of access to resources could impact the athlete's ability to participate at any level. Diaz stated that a common barrier to participation is a lack of resources, equipment, leagues, and opportunities for female athletes [6]. The interviews also affirmed the importance of information dissemination from a healthcare level about adaptive sports. If information about adapted sports is provided by healthcare professionals to neuropathic patients who may need it, this allows for an opportunity to become involved in this community sooner. Additionally, this can allow for earlier exposure to financial resources, and prevention of a sedentary lifestyle. Providing resources for access can also establish a stronger therapeutic alliance between the healthcare professional and the adaptive athlete.

One limitation of this research study includes only having the perspectives of five individuals with acquired diagnoses, only one of which was female. Another limitation is that we did not gather sociodemographic information to understand how this potentially impacts the athlete's experience with adaptive sports.

In conclusion, qualitative research has provided more insight about the factors that impact the lived experiences of adaptive athletes. Further research is still needed for quantitative health measures, and to better understand provider perspectives.

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IS PROPRIOCEPTION PREDICTIVE OF MOTOR LEARNING A NOVEL TASK: A RANDOMIZED CONTROL TRIAL

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INTRODUCTION

Proprioception is the ability to be aware of the position of the body through joint position sense, vibration sense, and limb velocity change [1]. The core receptors that assist in proprioception are muscle spindles, Golgi tendon organs, joint receptors, and cutaneous receptors [2]. One method to measure proprioception is by joint position sense (JPS). With eyes closed, a limb is moved to a target position with feedback then the individual is asked to replicate the position with no feedback. Error is measured by the difference in degrees from the intended joint angle. Impaired proprioception is associated with an increased risk of injury. Increased lateral ankle sprain frequency leads to greater proprioception impairment [3]. If the body is unaware of the ankle position in space, there is a higher chance of reinjuring it.

Motor learning is a relatively permanent change in skill due to practice [4]. It creates automaticity in a specific skill and allows the individual to complete the task in an efficient and accurate way. This contrasts with motor performance, which is a temporary change observed during the execution of the task and does not reflect true learning. Retention of a skill enables transference of the skill to other environments or similar tasks. It is generally assumed that better proprioception facilitates motor learning. There are no studies that compare an individual's proprioception and motor learning on a novel motor task. Previously, Han et al. found a significant correlation between proprioception and athletic performance. The more advanced the athletes were, their proprioception also increased [3]. However, this information does not support the process of motor learning. The skill was already learned, making the findings inconclusive to the relationship of motor learning and proprioception. The purpose of this study is to explore the potential relationship between motor learning and proprioception to develop new focuses on plan of care in rehabilitation. Researchers in this study hypothesize there will be a strong correlation between motor learning and proprioception as humans are adaptable in the sense of learning skill.

METHOD

Thirteen healthy participants were recruited (7 M, 5 F, 159.1lbs ± 43.5lbs, 68.7” ± 3.4”, 27.1 years ± 2.9 years). Exclusion criteria were current shoulder, wrist or elbow pain, pathologies, and dysfunction, as well as being a skilled dart thrower. Use of dominant or non-dominant arms were randomly assigned per participant.

Reflective markers and clusters were placed on the assigned upper extremity (UE) and trunk. Markers were tracked with a 10-camera motion capture system and used to calculate joint angles. The proprioception protocol involved twelve trials for the shoulder and elbow, and eight trials for the wrist. Participants were prompted to move their joints with auditory tones and memorize the position. High tones required the participant to elevate, while low tones required participants to decline at a given joint. An absence of tone indicating reaching the target angle. The shoulder and elbow were tested at 50°, 70°, and 90° of flexion while the wrist was tested at 30° of flexion and extension. The following trial required participants to replicate the joint position. Participants completed 100 dart throws after the proprioception protocol. Participants threw five darts at a time from a standardized distance. Darts were electronically marked through a program, which was then projected onto the target. Participants were informed knowledge of results. Coordinates were measured in pixels, which were then converted into centimeters. Participants then completed four additional dart throwing sessions within a7-9-day period, then performed a retention test a week after their last session.

Data was further analyzed, where absolute error and radian error were calculated. Absolute error values provided an indicator of accuracy for proprioception. Radial error values determined the distance of darts from the center of the target. A multiple regression analysis was performed with the dependent variable of change score from the first dart throwing session to the retention session and independent variables of JPS error at the shoulder, elbow, and wrist.

RESULTS

A paired samples t-test was conducted to compare Testing Session Average and Retention Test Average before and after training sessions. There was a significant difference in scores before ($M = 40.32$, $SD = 13.02$) and after ($M = 34.01$, $SD = 9.02$) the training sessions; $t(12) = 2.55$, $p = 0.013$, Cohen's $d = 0.71$.

A multiple linear regression was conducted to examine whether elbow proprioception, shoulder proprioception, and wrist proprioception predicted change score. The model was not significant, $F(3) = 0.60$, $p = 0.63$, $R^2 = 0.17$, adjusted $R^2 = -0.11$.

DISCUSSION AND CONCLUSION

Results from our study found a significant difference between participant's initial dart throwing session and their retention dart throwing session. This indicates motor learning occurred. However, the multiple regression analysis revealed there are no significant findings between the participant's motor learning change score and upper extremity JPS at the elbow shoulder, and wrist. This implies that a person's ability to sense their joint position in space has no effect on their ability to learn a novel motor task.

Although the current literature has researched the importance of proprioception in relation to movement planning, balance control, motor performance, locomotion, and other unique skills there still remains the question of the relationship between ML and proprioception. Previous findings discovered a relationship between shoulder proprioception and motor performance on water polo players. This study found that players with greater shoulder proprioception abilities presented greater acuity, strength, and range of motion [1]. In contrast, the results of our study found that UE proprioception had no influence on participant's ability to learn new motor skills.

Clinical application of our study can be employed in a variety of settings. For applications specific to physical therapy, this information can be helpful while treating patients that are returning to activity following an injury or post-operatively. Injuries to soft tissue structures and prolonged immobilization can impair proprioceptive abilities. Results from our study can inform clinicians that impaired proprioception will not have an effect on a person's ability to learn a novel motor task.

A key limitation of this study was the lack of specificity with feedback during dart throwing training sessions. By choosing to follow a dynamic systems theory approach to ML, researchers were reliant on participants identifying their errors and self-correcting. Another limitation is the sample size of our study. More participants are necessary to accurately describe the relationship between motor learning and proprioception.

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PROGNOSTIC FACTORS AFFECTING FALL RISKS IN ADULTS PARTICIPATING IN PHYSICAL THERAPY TREATMENT

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INTRODUCTION

Falls are a leading cause of injury, healthcare costs, and loss of independence among aging and neurological populations[1]. To maintain balance, a complex process involving the integration of the central nervous system (CNS) and coordinated input from the musculoskeletal and sensory systems must be regulated. Effective postural control required for balance maintenance relies on the integration of these six resources: biomechanical constraints, movement strategies, cognitive processing, control of dynamics, orientation in space, and sensory strategies[2]. Motor control and balance relies on sensory input incorporating vision, vestibular, and somatosensory feedback with coordination within the CNS to respond with the appropriate motor output and balance reactions. Despite the significant variance in neuropathology affecting the CNS, different neurologic disorders can impact similar neuroanatomical structures and have similar functional impairments affecting an individual's ability to generate balance responses.
There are established prognostic factors and risks which negatively impact balance and falls including: increased fear of falling, previous history of falls, and poor balance[3]. However, the influence of other prognostic factors such as dosage (frequency of visits), age, number of comorbidities, and chronicity (months since diagnosis) may interact with and have different impacts in heterogeneous neurologic diagnoses and pathologies which remain unclear. The purpose of this study was to determine the impact of therapy dosage and prognostic factors listed that correlate to a decrease in fall risk indicated by a participant's performance on an outcome measure appropriate for their clinical presentation. By improving our understanding of how treatment dosage affects balance in these populations, there is potential to guide clinical decision making to improve functional outcomes, reduce fall-related injuries, and improve quality of life. We hypothesized that neuroplastic capabilities are impacted by the interaction of disease pathology, prognostic factors, and therapy dosage.

METHODS

Participants were recruited through Spark Rehab + Wellness during their initial evaluation (T1). Individuals included were between 18 and 90 years old with a diagnosis of cerebrovascular accident (CVA), multiple sclerosis (MS), Parkinson's disease (PD), traumatic brain injury (TBI), or mild traumatic brain injury (mTBI), and initiation of a new episode of care. The study excluded those who have had therapy within 6 months prior to their evaluation, dementia or other cognitive impairment, and those with a prosthetic lower limb or considered non-ambulatory. Physical therapists were instructed not to change the plan of care of the participant and to document performed outcome measure scores correlating to the study. Outcome measures included: Functional Gait Analysis (FGA), Berg Balance Scale (BBS), Mini-BEST, Four Square Step Test (4SST), Four Square Step Test Cognitive (4SST-C), Timed Up & Go (TUG), Timed Up & Go Cognitive (TUG-C), Six Minute Walk Test (6MWT), and the Ten Meter Walk Test (10MWT). These outcome measures were grouped into categories of balance measures (FGA, Mini-BEST, BBS), dual task measures (4SST & 4SST-C, and TUG & TUG-C), and gait measures (10MWT and 6MWT). Outcome scores were collected at T1, 30 days (T2), and 90 days (T3). Patient responses were de-identified and input into Microsoft Excel. Data was analyzed using the Analysis ToolPak extension on Excel.

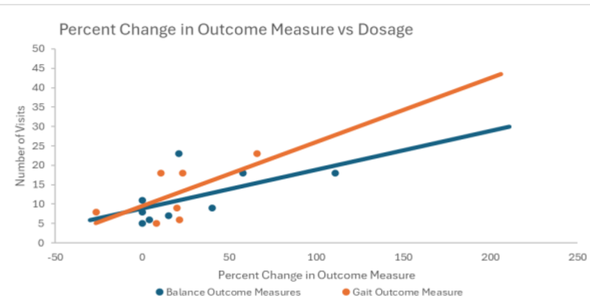

Figure 1. Relationship between percent change in balance related outcome measures and dosage (r=0.58, p=0.10) and gait related outcome measures and dosage (r=0.64, p=0.12)

RESULTS

The study enrolled 14 participants with the following diagnoses: 6 CVA, 4 PD, 1 MS and 4 mTBI. One participant's data was excluded from final analysis due to poor attendance affecting the timeliness of data collection, one participant's data was removed from the gait analysis due to inconsistencies in data collection. Demographics between groups were similar at baseline. Statistics were run between grouped outcome measures using percent change between T1-T3 and dosage, age, number of comorbidities, and chronicity for balance and gait outcome measures. Dual task outcome measure scores were removed due to lack of sufficient data.

Balance Outcome Measures

Correlations between percent change (27.57 ± 37.25) and dosage (11.67 ± 6.40, r = 0.58, p = 0.10), age (66.22 ± 13.42, r = -0.14, p = 0.71), number of comorbidities (1.44 ± 1.42, r = 0.00, p = 1.00), and chronicity (40.56 ± 66.94, r = -0.28, p = 0.47) were not statistically significant for balance outcome measures.

Gait Outcome Measures

Patients in the Fallers group demonstrated an average percent change of 44.62 (± 30.12), and a dosage of 20.50 (± 3.54), while participants in the non-Fallers group demonstrated an average percent change of 6.74 (± 19.43) and a dosage of 9.20 (± 5.17). A t-test showed no statistically significant difference between percent change (p=0.09). There was a statistical difference for dosage (p=0.04) between the two groups. There was no statistical significance in the correlations run between percent change (17.56 ± 27.28) and dosage (12.43 ± 7.09, r = 0.64, p = 0.12), age (68.57 ± 10.72, r = 0.29, p = 0.53), number of comorbidities (1.14 ± 1.46, r = 0.38, p = 0.40), and chronicity (24.43 ± 48.10, r = -0.17, p = 0.71) in gait outcome measures.

DISCUSSION AND CONCLUSIONS

The intent of this study was to explore prognostic factors for improvement in balance outcomes for neurologic populations with varying diagnoses. This study evaluated performance on outcome measures compared to dosage, age, number of comorbidities, and chronicity. This was performed without disrupting the participants' usual plan of care, to preserve clinical validity and protect patient-centered care. Prognostic factors for falls are established in current literature; however, it is unknown how these predictors interact with each other within neurologic populations. While most results were not statistically significant, they display trends that indicate a potential relationship between dosage, age, chronicity of the condition, and balance improvement. Both balance and gait improvements had a moderate positive relationship with dosage (r = 0.58, 0.64 respectively). This could be due to higher repetitions achieved, task-specific training, and consistent therapeutic feedback, all which drive the neuroplastic capabilities of the individual. For balance outcome measures, age and chronicity had a negative correlation with percent change. For gait outcome measures, percent change had a weak positive correlation with both age and comorbidities. This is contradictory to current research which suggest age and gait outcomes have a negative correlation, likely caused by decreased affinity for neuroplasticity and physiologic age-related changes, including reduced muscle fiber quantity, decreased bone mass density, and biomechanical alterations in tendons and ligament function[4,5]. For gait outcome measures, there was also a negative correlation between percent change and chronicity. This could be due to the progressive nature of degenerative conditions where function naturally declines over time despite therapeutic intervention. In more chronic non-degenerative conditions like stroke, longer chronicity may reflect secondary effects such as reduced activity levels, fear of falling, or other lifestyle changes that limit functional gains. This study was limited by the heterogeneity of diagnoses and outcome measures used for each participant, and limited sample size and inconsistent data collection. A study with greater power has the potential to show greater statistical significance to support the trends found in this study. While we were unable to draw conclusions for dosage, age, number of comorbidities, and chronicity, similarities in correlation trends between balance and gait provides an avenue for further exploration of these relationships in future studies with a larger, more homogenous sample size, as well as a longer follow-up period to better understand how to optimize fall prevention in neurologic populations.

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OSU SNOWBOARDING STUDY

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INTRODUCTION

Since its genesis in the 1960s, snowboarding progressed at an impressive rate across all disciplines (freestyle, freeride, and alpine). Snowboarding progression demonstrated that larger jumps require increased aerial time, allowing athletes to incorporate a greater number of rotations and inversions within a single maneuver. These are all jump based maneuvers, and the intrinsic and extrinsic factors limiting snowboard jump performance have not yet been identified in sport science literature. Research indicated that intrinsic factors, such as maximal strength, neuromuscular coordination, rate of force development, and reactive strength index (RSI) are key influencers of vertical jump height in athletes [1]. Extrinsic factors, including years of experience and training methods also influence jump performance [1]. Therefore, both intrinsic factors, or neuromuscular (NM) capacity, and extrinsic factors, or on-snow skill (OSS), may play critical roles in enhancing jump performance and advancing snowboard progression

The purpose of this study was to identify the limiting factors of snowboarding jump performance and to determine whether jump performance in elite snowboarders is more strongly influenced by NM capacity or OSS. In snowboarding a preferred stance (regular or goofy) meant the athlete favored a specific lead leg (LL) and trail leg (TL), whereas the opposite stance was called switch. We hypothesized that, regardless of riding stance (regular or switch), riders would generate greater peak force through their dominant leg while on-snow, suggesting that jump performance is primarily dependent upon NM capacity. Dominant leg is defined by the higher RSI value during on-land testing. Conversely, if greater peak forces were observed in either the TL or LL across both stances, it would indicate that OSS was the more influential factor. Current best practice emphasizes NM capacity training and neglects OSS performance.

METHODS

Six elite snowboarders (5 male, 1 female), aged 27-51, who competed professionally for at least 5 years and had no acute injuries within the past 6 months, volunteered to participate and signed consent forms prior to participation. The study was IRB approved and conducted on a controlled portion of the mountain with permission from Mt. Bachelor. Due to the inherent measurement challenges of real-world snowboarding, traditional laboratory-based assessments were deemed inappropriate for evaluating jump performance on snow, requiring us to use wearable technology. The order of on-land or on-snow testing was randomized based on participant arrival.

On-land testing: Participants performed a single-leg hop test for 10 seconds for both right and left leg for jump testing with the Runeasi IMU (Leuven, Belgium) to measure RSI for each leg, defined as the ratio of flight time to ground contact time. RSI is widely used to assess an athlete's ability to produce explosive force during the stretch-shortening cycle and is a valid measure of lower-limb neuromuscular capacity [2].

On-snow testing: Xsensor (Calgary, Canada), a plantar pressure insole system, was used to measure peak load at takeoff during each trial. The use of Xsensor allowed for valid on-snow measurement in a real-world environment [3]. Each participant alternated between stances, for a total of 3 regular stance and 3 switch stance jumps. Participants were given approximately 50 meters of runway, marked with a cone, to get to their desired speed each jump. They were provided standardized instructions to, "jump as high as you can when you reach the cone." Participants returned to the top of the runway for each trial. A paired t-test was used to assess statistical significance for peak loads between TL and LL. The alpha level was set at $p = < 0.05$ for all statistical comparisons.

RESULTS

With respect to neuromuscular capacity: RSI Percent Difference varied widely among participants (see Table 1). There was no significant difference found for Percent Difference in Peak Load between TL and LL. Figure 1 represents the number of riders that utilized neuromuscular capacity to jump versus those who used OSS to jump. 1/6 of the participants used neuromuscular capacity, indicating that they always produce more force with their dominant leg regardless of their stance. Meanwhile, 5/6 participants used OSS, indicating that they produced higher forces either only on their LL or TL respectively. Out of these 5 participants, 4 of them produced higher forces on their TL and 1 of them produced higher forces on their LL regardless of stance.

Table 1: NM capacity measured on land vs OSS. Colors correlate to the key in Figure 1. A T-test was performed for the percent difference of TL and LL.

	NM Capacity	On-Snow Skill Peak Load	
Participants:	RSI Percent Difference	Percent Difference of TL	Percent Difference of LL
1	3.32%	17.52%	3.26%
2	77.78%	-28.59%	4.65%
3	38.36%	5.22%	-40.22%
4	13.79%	0.21%	-11.50%
5	11.96%	12.89%	-17.88%
6	5.95%	14.54%	-39.39%
Averages:	22.44%	3.63%	-16.85%
SD:	25.11%	15.54%	18.03%
		T-test Percent Difference of TL and LL:	0.1682

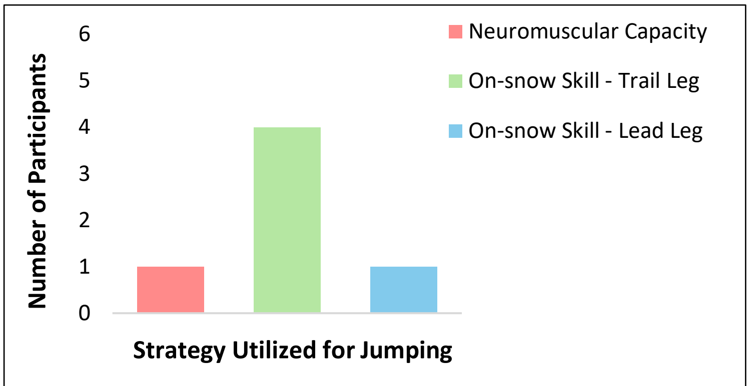

Figure 1: Number of participants that utilized NM capacity versus OSS, irrespective of stance, to perform a jump.

DISCUSSION AND CONCLUSIONS

Previous snowboarding research identified intrinsic NM capacity of professional riders in a lab-based environment as well as the importance of assessing the OSS of these athletes. However, the two concepts have never been investigated together to explore the rate limiting factors of elite snowboarding performance. Research has shown strength asymmetries between the front and rear legs of elite alpine snowboarders [4] which was confirmed by our research as seen in the RSI Percent Difference of each athlete in Table 1. Harding and James proposed the need for better assessment of OSS, specifically airtime, as it relates to professional half-pipe snowboarders [5] which correlates with our findings related to OSS in Table 1.

We gave the cue, "jump as high as you can," allowing riders to utilize their individual jump strategy; a TL dominant technique, a LL dominant technique, or no preference for TL or LL – implying a NM dominant technique where the higher RSI leg would dominate no matter their riding stance. Riders who preferred OSS, maintained jump strategy regardless of riding preferred or switch. We found the OSS of a professional snowboarder was a better predictor of their snowboard jump performance than their NM capacity. Additionally, riders who showed a preference for OSS tended to have greater asymmetries in their NM capacity, elucidating the importance of on-snow training for return to sport (RTS). Current rehab focuses primarily on NM capacity for RTS, which is inconsistent with our findings and implicates the need for individualized NM capacity and OSS protocols for professional snowboarders. We suggest periodic, individualized baseline testing to find where athletes fall on the spectrum of NM capacity to OSS and what is limiting their performance.

Our study was mainly limited by its high variability between participants, as shown by the standard deviations in Table 1, and our small sample size. We recommend that future research investigates the optimal method for testing OSS, additional limiting factors to snowboard performance, and potential intervention strategies. This would better guide our performance testing of professional snowboarders to help them meet the standards of an increasingly demanding sport.

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STANDARDIZATION OF BREAST CANCER-RELATED LYMPHEDEMA LIMB CIRCUMFERENCE AND VOLUME CALCULATION

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INTRODUCTION

Breast cancer-related lymphedema (BCRL) is a secondary lymphedema, caused by damage to the lymphatic system during cancer treatments such as radiation or surgical removal of lymph nodes [1]. The damage to lymphatic structures leads to lymphatic insufficiency and fluid buildup in the upper extremity (UE), chest, and neck [2]. As of 2022, BCRL impacted approximately 20% of survivors of breast cancer, most commonly within the first 2 years of treatment [3]. BCRL may result in upper quadrant functional impairments, decreased participation in social activities, higher medical costs, and a lower quality of life [4].

Although there is more than one reliable and accurate way to measure limb volume in patients with BCRL [5], it is crucial to focus on feasibility and the cost of equipment. The Clinical Practice Guideline (CPG) For Diagnosis of Upper Quadrant Lymphedema Secondary to Cancer [5] recommends that volume should be calculated via circumferential measures (*Grade B*) and calculated volume differential standard is used to rule in lymphedema *(Grade B).* The CPG also states that water displacement may be used in diagnosing lymphedema but is limited by clinical utility *(Grade B).* The CPG recommends that using a frustum formula to calculate the volume of the UE best represents the true shape of a lymphedematous limb, and there is evidence suggesting that smaller increments of measure are more highly correlated with water displacement measures when taken at one time point [5]. However, there is a gap in the literature describing which increment of circumference measure is most responsive to change over time. This has clinical importance as change over time drives physical therapy clinical decisions, such as surveilling for the development of BCRL and in assessing the effectiveness of BCRL treatment.

The purpose of this study was to investigate which increment of circumferential measurement is most responsive to change over time in those with BCRL. It was hypothesized that the smallest increment of circumference measurement, 2 centimeters (cm), would be the most responsive to change.

METHODS

Participants with unilateral UE BCRL who were receiving rehabilitation to treat their BCRL were recruited from physical therapy clinics in Central Oregon. Eligible participants (age >18, history of breast cancer) completed three study visits, spaced seven days apart.

Data was collected by a team of one licensed physical therapist and four student physical therapists (SPTs). An interrater reliability study confirmed that all evaluators were suitably trained. We obtained excellent reliability between measurers, Chronbach's alpha of 0.999, and an ICC of 0.998 with a p-value of <.001.

For the study procedure, the participants placed their arm into the water-filled volumeter. A line was drawn to indicate how much of the upper limb was submerged. The displaced water volume was measured by weight (g) according to standardized procedures [4]. Circumferential measurements were taken at 2 cm intervals along the arm until the water displacement line was reached using a Gulick spring-loaded tape measure. The volume of the arm was calculated using 2 cm, 4 cm, 6 and 10 cm increments utilizing a frustum equation [5]:

$$V = \frac{1}{12\pi}\sum_{i=1}^{n} L({C_i}^2 + C_i C_{i-1} + {C_{i-1}}^2)$$

Our statistical analysis was performed using IBM SPSS Version 29.0.2.0. A correlation analysis was performed to identify which increment of measure was most highly associated with the gold standard, water volumetry. A repeated measures ANOVA was conducted to evaluate whether estimated limb volumes differed significantly across time points and measurement increments of circumferential data.

RESULTS

A total of two females with an average age of 51.5 years were enrolled in the study. Both were actively being treated for symptoms of lymphedema at the time of the study.

Increment of measure (cm)	Pearson correlation	P- value
2	.576	.232
4	.557	.251
10	.164	.756

Table 1: Association between volume calculations using different increments of measure and water displacement volume

A repeated measures ANOVA revealed no significant difference between volumes calculated using different increments of measure over time $F(1.00, 1.00) = .772$, $p = .427$.

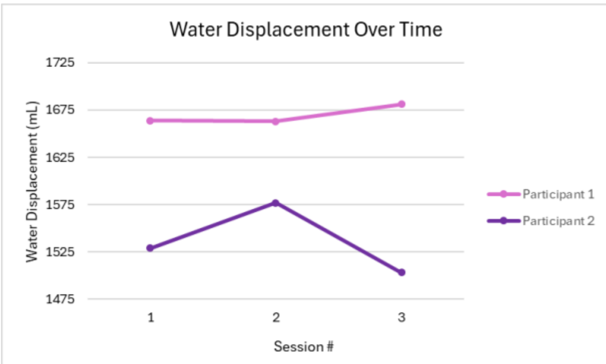

Figure 1: Volume change over time for participants as measured by water displacement

DISCUSSION AND CONCLUSIONS

We did not find statistically significant evidence that suggested any one circumference increment was better at detecting change over time. Our circumference measures were also not significantly correlated with the gold standard measure, water displacement. This was surprising, as Sander, et al. [5] found robust correlations between 3cm, 6cm, 9cm frustum geometric volumes of the arm and water volume with an r value of .97-.98 ($p < .01$). This may be due to our small sample size, lack of reliability between raters for water displacement, and/or the lack of active changes in limb volume for the participants (Figure 1).

Limitations included that our participants were experiencing early stage lymphedema with minimal visible edema. Therefore, as shown in Figure 1, our participants experienced a relatively small change to volume over time, despite being in active treatment to manage their lymphedema. Additionally, the study was underpowered with only two participants. Strengths include the high reliability of our circumferential measures minimizing the chance of measurement error and strengthening our ability to detect change over time.

Future research should include participants who have a higher initial limb volume to be reduced over time to allow these measures to truly assess for change over time. It is difficult to detect meaningful volumetric changes when the participant starts the study with minimal edema. With the significant prevalence of BCRL following cancer treatment, the importance of using a measure that has a high ability to detect change over time to aid with early diagnosis and assessment of effectiveness of lymphedema treatment is key to positive health outcomes. Standardization of this measurement is paramount.

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THE EFFECT OF TRAIL RUNNING FOOTWEAR ON DOWNHILL RUNNING BIOMECHANICS

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INTRODUCTION

Running is a globally practiced sport and form of exercise that continues to grow in popularity. Understanding the biomechanics of running allows researchers, coaches, and athletes to quantify the characteristics of efficient human movement in the sport. Running biomechanics may be subject to variability due to both intrinsic and extrinsic factors. Understanding how running biomechanics may be altered by intrinsic and extrinsic factors is of interest to runners and the professionals that work with them because it may provide insight into running-related injuries and performance optimization [1]. Shoe type as an extrinsic factor is of particular interest due to its potential for modification.

Previous research has investigated ankle kinematics on flat road and trail surfaces [2], the effects of stack height on ankle kinematics on a flat laboratory surface [3], and the biomechanics of downhill treadmill running in minimal shoes [4]. However, a knowledge gap remains regarding how specific shoe features, including stack height and tread affect downhill running biomechanics on a trail surface.

The purpose of this study was to examine the downhill running biomechanics of recreational trail runners wearing the following zero drop shoe types: maximal trail running shoes with traction lugs and traditional trail running shoes with and without traction lugs. It was hypothesized that there would be an increase in ankle eversion excursion and peak knee flexion angle when trail running downhill in shoes without traction lugs, and an increase in ankle eversion duration when trail running downhill in a maximal shoe.

METHODS

Fifteen (8 female, 7 male) recreationally active adults (age: 34 ± 7 years) participated in this study. Relevant inclusion criteria were a weekly running milage of at least 15 miles and some amount of weekly trail running. Exclusion criteria were a recent injury (within previous 3 months), known cardiovascular or neurologic disorders, and current pregnancy. Participants were recruited via social media, community flyers, and direct researcher outreach.

Participants ran on the same downhill section of trail (approximately 70 ft) on OSU-Cascades property at their usual easy run pace five times per shoe condition. The following shoe conditions were utilized: traditional shoe with tread (Altra Lone Peak 9's with intact trail lugs), traditional shoe without tread (Altra Lone Peak 9's with shaved lugs), and maximal shoe with tread (Altra Olympus Trail 6's) and were randomized for each participant. Participants were given two practice trials per shoe condition to normalize their pace. Two researchers measured the time spent between two fixed landmarks placed 50 feet apart to ensure a consistent pace. Trials outside of the desired time range, as calculated by the average of the practice trials ± 0.25 sec, were not analyzed. Video of the participants was captured with a markerless motion capture system that utilized ten calibrated Sony RX0II cameras. Lower extremity kinematics were calculated in Theia3D and further processing and data extraction was performed in Visual3D. Researchers manually identified foot strike and toe off for one step of the dominant limb using Visual 3D. Foot strike was defined as the first frame that the foot contacted the ground and toe off was defined as the last frame that the toe was in contact with the ground. Statistical analysis was conducted using a repeated-measures ANOVA between 3 shoe types for each participant (α = .05) in JASP software. Post-hoc analyses were performed when appropriate using a Bonferroni correction.

RESULTS

The inversion angle at initial contact was greater in the maximal shoe condition compared with the traditional shoe condition (p = 0.04). No other significant differences were found in analysis of all other kinematic variables between the three shoe conditions (Table 1).

Table 1: Kinematic Variables of Interest

Shoe Condition	Maximal	Traditional	No Tread	*p*-value
Eversion EXC	3.95±3.22	3.29±2.57	3.22±2.74	0.252
Inversion at IC	4.43±4.12	2.91±3.76	3.09±3.56	0.040*
Dorsiflexion at IC	-11.67±7.16	-12.19±9.34	-13.74±9.08	0.129
Peak Dorsiflexion	12.19±3.91	11.61±4.71	11.82±3.76	0.577
Dorsiflexion EXC	23.88±6.80	24.51±9.56	25.56±8.32	0.304
Peak Knee Flexion	61.54±7.44	60.86±8.49	59.54±7.24	0.158
Knee Flex EXC	45.01±8.15	44.17±8.83	43.29±9.39	0.458

*Means and standard deviations are reported above. * denotes a statistically significant value ($p < 0.05$).*
EXC= excursion; IC= Initial contact

DISCUSSION AND CONCLUSIONS

Across all kinematic variables measured, only one statistically significant variable was found. The average angle of ankle inversion at initial contact was greater in the maximal shoe condition as compared to the traditional shoe condition (p = 0.04). This finding is in contradiction to previous research [5], which found that when running on a flat, hard surface in a maximal shoe condition, runners displayed decreased ankle inversion at initial contact. Additionally, other previous, similar studies [3] have shown prolonged eversion and increased eversion duration under maximal shoe conditions, but this finding was not demonstrated in this study. One potential implication of this study's finding of increased ankle inversion at initial contact in a maximal shoe during downhill trail running is the potential increased risk of lateral ankle sprain due to this change in ankle kinematics. The primary mechanism for lateral ankle sprains is believed to be ground contact with the ankle in a position of relative inversion and plantarflexion [6]. Due to the limitations of this study, further research is warranted to determine if this kinematic variable is consistent, and if there is a relationship between maximal shoe choice for downhill trail running and increased incidence of lateral ankle sprain.

One limitation of this study is that it was underpowered, with n=15 and a power analysis result of n=22. To see other potentially present significant results, further studies with more participants must be performed. A second limitation was the use of manual identification of heel strike and toe off, performed by seven researchers, which could have affected accuracy and reliability of the biomechanical events.

In this study, the shoe characteristics of stack height (maximal or traditional) and presence of tread did not grossly change downhill running mechanics on a trail surface. It is possible that this study did not capture differences in biomechanics due to the study being underpowered, selection of shoes with too many similar characteristics, differences in foot strike pattern obscuring trends, and the undetermined accuracy and reliability of the manual identification of biomechanical events. Additional studies on this topic are necessary to glean further understanding of the effect of shoe characteristics on downhill trail running biomechanics.

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LOWER EXTREMITY BIOMECHANICAL FACTORS AND FUNCTIONAL PERFORMANCE OF PICKLEBALL PLAYERS

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INTRODUCTION

Pickleball continues to be the fastest growing sport in the United States the past 5 years [4]. As the sport continues to grow, there is an increasing rate of lower extremity injury among pickleball athletes. Despite this rapid growth, there is limited literature on knee biomechanical factors or aerobic capacity in pickleball players. In pickleball, rapid movements like running, jumping, and/or cutting are required. Movements such as these can predispose players to injury if they do not have the prerequisite knee muscle performance, agility, and/or stability. The aim of this study was to measure these biomechanical factors and aerobic capacity in a cohort of pickleball players, comparing data across age, gender, frequency of play, and Dynamic Universal Pickleball Rating (DUPR). It was hypothesized that pickleball players at a higher DUPR level would have a higher VO2 max and would be able stabilize during a dynamic hopping task; players who have a greater frequency of play would have faster agility times; and those who play more frequently would have higher emotional well-being (EWB) and social health.

METHODS

Participants: Flyers and online posts placed at local pickleball courts and groups in Central Oregon for recruitment. Inclusion criteria included being 18 years old or older and participating in pickleball at least once per week. The exclusion criteria were if they felt any pain in their chest or dizziness at rest, during daily activities, or during physical activity; if they had any lower extremity injuries in the past six months, or ≥4/10 pain in their lower extremities at rest and/or during activities. 24 participants (11 female, 13 male) were selected based on eligibility criteria. Participants had an average pickleball DUPR of 3.8 ± 0.6. This aligns with the national average, falling between 3 and 4.
Procedures: Phone interviews were conducted to determine eligibility and to gather demographic information. Upon arrival, participants signed informed consent forms and filled out the SF-36 questionnaire regarding their physical and mental health, followed by a warm-up. The stations were completed in the following order: Force Plate testing, Modified Agility T-test (MAT), YMCA 3-minute Step Test, and Biodex Dynamometer. For time to stabilize (TTS), participants were instructed to jump from a standardized starting position and land with one foot on the force plate recording their motion. TTS was determined when the participant's vertical ground reaction force fell between 5% of body weight measured in Newtons [6]. The modified agility T-test (MAT) is a validated assessment tool used to measure speed with directional changes forward, laterally, and backwards. Participants were instructed to run and shuffle as fast as they could, following previous protocols [5]. The YMCA 3-minute step test was performed to determine the participant's VO2 max. Their post-test heart rate, age, and gender were used to calculate their VO2 max which was then classified into 1 of 6 rankings from VO2 max norms [2] The Biodex Dynamometer assesses leg strength through knee flexion/extension at varying resistance levels, following previously established protocols [3]. Knee flexion and extension peaks, and hamstring to quadricep ratio were collected for both lower extremities.
Statistical Analysis: Using Excel, statistical analyses were performed using correlation comparisons and two-tailed T-tests comparing data collected during the experiment. An alpha level of 0.05 was used to determine significance.

RESULTS

Analysis revealed that skill level was not associated with VO2 max, MAT, or quad/hamstring ratio, but it was associated with ability to stabilize. Analysis of frequency of play showed that playing more than 4 times per week was associated with greater general health. Additional analysis showed faster MAT times were associated with higher peak flexion (>60N/m) and extension (>100N/m). The ability to stabilize was also associated with a faster MAT time. Significant findings are in **Table 1** with an orange highlight and trending towards significance is in yellow highlight.

Table 1: Two-tailed T-tests and Correlation Statistics (statistically significant highlighted in orange)

Variable 1	Variable 1 Avg	Variable 1 Avg	Groups	Variable 2	Variable 2 Avg	Variable 2 STD	P-Value	R-value
DUPR	3.81	0.59	>4 vs <4	**VO2 Max**	41.9	5.9	0.7114	-0.0017

DUPR				**Time to Stabilize**				
Right	3.81	0.59	>4 vs <4	Right	3.18	1.23	0.055	0.376
Left	3.81	0.59	>4 vs <4	Left	3.17	2.055	0.055	0.376
Frequency of Play	2.33	0.56	<3 days vs >3 days/wk	**T-agility (sec)**	11.29	2.75	0.12	-0.296
Frequency of Play	2.33	0.56	<3 days vs >3 days/wk	**Emotional Well-being**	86.5	8.4	0.65	-0.18
Frequency of Play	2.33	0.56	<3 days vs >3 days/wk	**Social Functioning**	95.3	8.88	0.828	0
Frequency of Play	2.33	0.56	<3 days vs >3 days/wk	**General Health**	82.9	14	0.069	0.365
Flex/Ext Peak (N/m)			Flex >60 n/m, Ext >100n/m	**T-agility (sec)**				
R Flex 60	69.8	31.5			11.29	2.75	0.00429	-0.611
R Ext 60	115.75	56.8			11.29	2.75	0.0022	-0.593
L Flex 60	69.75	27.78			11.29	2.75	0.0022	-0.624
L Ext 60	102.65	52.8			11.29	2.75	0.0021	-0.635
T-agility (sec)	11.29	2.75	T-agility > 12 sec	**Quad/Ham Ratio**	70.34	9.15	0.126	0.342
Emotional Well-Being (EWB)	86.5	8.4	EWB score > 90 vs <90	**VO2 Max**	41.9	5.9	0.013	-0.251
Injury History	0.5	0.51	Injury vs Not injured	**VO2 Max**	41.9	5.9	0.009	-0.542

DISCUSSION AND CONCLUSIONS

Analysis of the data confirmed the hypothesis that pickeball players at a higher DUPR level would have the ability to stabilize during a dynamic hopping task. The lack of correlation between frequency of play and faster MAT times or EWB demonstrates that these factors may not influence performance but may require further investigation. When comparing DUPR rating with VO2 max, there was no significant relationship between these variables. As a result, VO2 max does not appear to be a requirement for skilled play.

Analysis of additional variables did reveal that VO2 max was linked to a participant's injury history and EWB. This suggests that a higher VO2 max may lower a player's injury risk. However, as this study was not exclusive to injury investigations, further research is needed to explore this relationship. EWB was also associated with a higher VO2 max, as those who scored higher than a 90 on the SF-36 were more likely to have a higher VO2 max. Participants who generated higher peak torque during the 60 degrees/second trials for flex/ext on the Biodex exhibited faster MAT times. Meaning, incorporating power training could translate to faster sport performance. When comparing MAT times to participants who stabilized and those that did not, it was found that participants who did, had a faster MAT time. This indicates a greater ability to statically stabilize may improve the capacity to quickly change direction. A recent study investigating falls in recreational pickleball players found that participants with faster agility tended to report less falls [1]. This correlation aligns with our findings of faster MAT times being associated with muscular power measures, supporting the importance of power development in fall prevention programs [1]. The main limitation of this study was having a small sample size (n-24). Future research with a larger sample size is warranted to confidently make recommendations to improve pickleball performance and injury prevention programs.

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