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Effects of Simple Postural Instructions on Running Form Modification in Recreational Runners – Preliminary Findings

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EFFECTS OF SIMPLE POSTURAL INSTRUCTIONS ON RUNNING FORM MODIFICATION IN RECREATIONAL RUNNERS – PRELIMINARY FINDINGS

By

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A doctoral project submitted in partial fulfillment

of the requirements for the

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Department of Physical Therapy

School of Allied Health Sciences

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University of Nevada, Las Vegas

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Doctoral Project Approval

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This doctoral project prepared by

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entitled

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Doctor of Physical Therapy
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ABSTRACT

Background and purpose: Running is one of the most popular exercises but it is also an activity with a high incidence of injury. Running form modification involving a forward lean of the trunk and forefoot strike pattern has been shown to be effective in attenuating the impact forces of the lower extremity. However, it is currently unknown how these changes can be most effectively instructed and learned by the runners. Previous studies have shown that practicing a motor task with an external focus can facilitate learning and retention when compared to the more common internal focus instructions. The purpose of this study is to examine the effectiveness of external and internal attentional focus cues on trunk posture and peak vertical ground reaction force (GRF) during the stance phase of running.

Subjects and Methods: Ten recreational runners were selected for this study and randomly assigned tone of two groups receiving external or internal instructions designed to modify their running form. Trunk posture and GRF were obtained using a 3D motion capture system and a force plate instrumented treadmill while running at 2.5 m/s and a self-selected speed. Subjects were tested over a 5-week time period consisting of 4 sessions over a 4-week training program, followed by a final session 1 week after the training program to analyze retention of running form modification.

Results: Overall there was a significant increase in trunk angle observed over time, following instruction, for both groups at speed 2.5 m/s. Running at speeds 2.5 m/s and a

self-selected speed showed no statistically significant difference in increased trunk angle or GRF when comparing an internal versus external attentional focus.

Conclusion: Simple postural instructions were shown to be effective for inducing greater trunk lean during running. This study found no difference in trunk angle or GRF when comparing internal and external attentional focus groups. Future studies would benefit from using clear and proper instructions that incorporate internal and external attentional focus cues with feedback to reinforce motor learning.

Clinical Relevance: Alterations to a person's running form, specifically an increased trunk angle and forefoot strike pattern, may lead to a decrease in running related injuries due to its reduced knee loading and decreased GRF loading rate. Based on our findings, we conclude that simple postural instructions and training over 4 weeks can induce changes in trunk angle during running. However, due to the small sample size and other methodological limitations, we could not determine which attentional focus is more beneficial. Future studies should focus on the influence of instruction and feedback on running form modification training, which can help facilitate health and prevent musculoskeletal injury during running.

ACKNOWLEDGEMENTS

We would like to take this opportunity to express our gratitude to all of the subjects who participated in this research project for all their time and dedication. We would also like to thank Dr. Wülf for her knowledge and contribution in preparation for this study. Dr. Lee for his leadership and mentorship during the entire process of research and data analysis. Josh Bailey for his help and guidance in data collection. Christian Johnson for his time and dedication towards processing and analyzing data. And Finally, Dr. Ho and Dr. Liang for their support in writing and development of our research paper.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Running has become one of the most popular forms of exercise and continues to increase in the number of participants. Running is not only a competitive sport, but has also become a leisure-time activity that many people enjoy. Accompanying this increase in popularity is an increase in injury rates. Several studies estimate 56-90% of recreational runners sustain an injury each year with approximately 50% affecting the lower extremities, primarily the knee, due to excessive joint loading and higher initial vertical loading rates. [1] Many new forms of running have been established to combat this increase in injuries, a popular one being ChiRunning. ChiRunning is a running form that encourages runners to run tall, lean forward, and use a forefoot strike running pattern. [2] A 2012 study showed ChiRunning results in reduced impact and higher running efficiency when comparing a rearfoot strike pattern to an anterior foot strike. [3] This study also found ChiRunning had a greater attenuation of impact, less knee extensor eccentric work, and less braking force. The researchers found that traditional running forms using a heel strike foot pattern exhibit increased ground reaction force, which could be responsible for many running-related overuse injuries. [3] Running with a flexed trunk or forward lean posture has also been shown to have a reduced demand on the knee extensors. [4] This may be due to the fact that a forward trunk lean moves the ground reaction force vector more anteriorly and it reduces the demand of the knee extensors. [5]

While we know conceptually it is possible to reduce the risk of running-related injuries by running form modification and re-education, the efficacy of simple instructions to promote such changes are currently unknown. Motor skills can be taught through instructions that promote different attentional foci, including an internal attentional focus and an external attentional focus. [6] An internal focus has been defined as a focus on body movements. An example of this is focusing your attention on leaning your trunk forward and landing on the front part of your foot during running. Having an external focus means the attention is directed to the effect of the movement on the environment. An example imagining a string pulling you forward and landing on the front part of your shoe. When comparing these two forms of attentional focus, many studies have shown that the effect of motor learning can be enhanced by using externally focused instructional cues. [6] An external attentional focus has been shown to promote a more effective and efficient movement, providing a higher level of accuracy and consistency in achieving a movement goal and more fluent and coordinated movement executions. [6] This advantage has been shown over many different motor tasks and skill levels, including golf swing and putt, volleyball serve, soccer, football kicks, basketball free throw, throwing accuracy, piano, and gymnastics routine. [6] An external attentional focus appears to expedite the learning process as well. This is thought to be due to the fact that an external focus promotes automatic and unconscious control of movement, whereas an internal focus on one's own movements promotes a conscious control of movement, thus constraining the motor system. [7] This is also known as the constrained-action hypothesis, which gives a possible reason for the advantages of focusing on the effects of one's movements, rather than on the movement itself. The constrained-action hypothesis explains that an internal attentional focus, where the participant focuses on their movement, may interfere with automatic control processes that normally regulate movement versus an external focus, allowing the motor system to self-organize and be unconstrained by conscious control. [8] The automaticity resulting from an external focus will reinforce the idea that it is more effective for motor skill learning and performance. [7] A running form modification training program with externally focused instruction may enable more effective learning and retention of the modified running style.

Although there have been many studies showing the benefits of having an external focus on motor learning, there has not been any research on running form reeducation with attentional focus. Motor skills that are judged by form, for example running form has been rarely used in attentional focus studies. [6] We know that running with a forward trunk lean and a forefoot strike pattern can reduce forces on the knee, but we have not seen if runners can effectively learn and retain this running form using simple attentional focus instructions.

The purpose of this study is to examine the effectiveness of the internal and external focus based instruction on retention of running form modification training. The results and information gained from this study will not only benefit runners and clinical physical therapy practice, but will also help us understand the effects of simple instructions on motor learning. Specifically, we designed a 4-week training program to measure the difference in retention between internal and external attentional focus in helping to maintain a correct forward lean posture and forefoot strike. We hypothesize that modification of running form using an external attentional focus will result in lower ground reaction force and increased trunk flexion angle.

METHODS

Subjects

A sample of convenience of ten recreational runners from the southern Nevada region was recruited to participate in the study. Determining the experience level of each subject was based on the average distance ran per week and how many years of running experience they had. The inclusion criteria for the participants were: 1) age between 18-45 years, 2) free of any lower extremity injury at the time of the study, and 3) recreational runners currently running at least 3 times or 5 miles per week. Any participant with a history of cardiovascular or respiratory disease, joint replacement, ACL reconstruction, or any acute lower extremity injury were excluded from the study. Prior to participation in this running study, each participant had the objectives, procedures, and risks of the study explained to them. Informed consent approved by the Institutional Review Board of the University of Nevada, Las Vegas was obtained from each participant.

Instrumentation:

Participants were tested on a force platform-instrumented treadmill (Bertec Corp., Columbus, OH, USA), which collected data on the ground reaction force (GRF) during running. The GRF was sampled at 2000 Hz. The three-dimensional kinematic data including the trunk and lower extremity angles was captured by a 12-camera Vicon digital motion system (Vicon, Oxford Metrics, Oxford, UK) at 200 Hz. Twenty-five reflective markers were placed over the following anatomical landmarks of the trunk and lower extremity: bilateral acromions, anterior and posterior superior iliac spine, iliac crests, L5 spinous process, greater trochanters, medial and lateral femoral condyles, medial and lateral malleoli, 5th metatarsal head, 1st metatarsal head, and tip of 2nd toe. Thigh and calf clusters were placed bilaterally on the lateral mid-thigh and lateral calf respectively. Heel clusters were placed on the outside of the shoe bilaterally, and a back plate was placed between the scapula using straps to help secure the plate.

Procedures

The ten participants who were eligible for the study were broken into two groups in a semi-random order consisting of 5 subjects in each group. The first group received an external attentional focus (EF) cue to “imagine a string pulling you forward” and “landing on the front part of your shoe”. Participants in the second group received an internal attentional focus (IF) cue to “lean your trunk forward” and “land on the front part of your foot” (Table 1). Data was collected in the clinical Locomotor Neuromechanics Laboratory located at the University of Nevada, Las Vegas. Each participant was tested over a 5-week running modification program. Running form was analyzed over 5 time points (Table 1), consisting of Session 1A (pre-instruction), Session 1B (immediate post-instruction), Session 2 (2 weeks post-instruction), Session 3 (4 weeks post-instruction), and Session 4 (1 week retention post training program).

At the beginning of the session, participant’s weight and height were recorded. Then 25 markers were then placed over their correct anatomical landmarks of the trunk and lower extremities. Participants were then instructed to stand on the treadmill with arms abducted to 90 degrees while a static calibration video was taken using the Vicon system. Marker and ground reaction force data was then captured using the specific running protocol.

Biomechanical Testing

Each group participated in a pre-instruction running session (Session 1A). During this time, participants ran on the treadmill while using their usual running form. The runners were given a 5-minute warm up period at a self-selected speed and then asked to run for 2 minutes at the pre-determined speed of 2.5 m/s and at a self-selected speed of what they would normally run at. The participants were given one minute to acclimate to each speed before data collection occurred in three trials, with each trial lasting 20 seconds in duration. Once the participants completed the first running protocol, the runners were given a 10-minute rest break in order to recover. During this time, the participants were given internal or external attentional focus cues (Table 2), depending on their predetermined attentional focus group.

During the Session 1B, each group applied their respective running form attentional focus cues in order to alter their normal running form. The runners participated in the same running protocol as Session 1A, which consisted of a 2-minute warm-up at a self-selected speed and running 2 minutes each at the predetermined speed of 2.5 m/s and at a self-selected speed. The internal and external attentional focus cues were reinforced by repeating each instruction while the participant was running. Sessions 2 and 3 followed the same running protocol as Session 1B. Session 4 consisted of the same running protocol without the running form modification instructions being reinforced.

Data Analysis

Using the Vicon digital motion-capturing system, each reflective marker was labelled correctly corresponding to its anatomical landmark and each running trial was cut and edited to include 10 consecutive steps or 5 consecutive stride lengths. These labelled files were then transferred to the Visual 3D software (C-Motion, Rockville, MD) where each trial was viewed to ensure labeling was done correctly. The biomechanical outcome measures of interest are GRF and trunk angle. The mean GRF and trunk angle data was obtained from each of the three, 20-second running trials to determine the peak GRF and trunk angle in each stance phase (10 total), then averaged. A customized MatLab (MathWorks, Natick, MA) program was used to perform this analysis.

Between-day reliability of measuring the trunk kinematics during running has been established ($ICC_{3,1}$=0.866, absolute agreement) prior. The standard error of measurement based on the between subject variance and reliability was 2.74 degrees.

Statistical Analysis

Differences in age, height, weight, years of running, and runs and distance ran per week between the internal and external groups were evaluated using independent t-tests. A 2-way (2 x 5, group by time) mixed ANOVA was used to compare the GRF and trunk angle between the internal and external groups in each 2 running speed condition (2.5 m/s and self-selected speed). When significant ANOVA main effects or interaction were detected, appropriate post-hoc analyses with Least Significant Difference adjustment were conducted. Level of significance for all analyses was set at $\alpha = 0.05$. Data was analyzed using SPSS Statistics version 22 (International Business Machines Corp., Armonk, NY, USA).

RESULTS

There was no statistically significant difference in age, height, weight, number of years running, number of running sessions per week, and number of miles ran per week (Table 3).

For the 2.5 m/s running speed, we observed no significant difference in GRF between the internal and external groups ($p = 0.145$; Figure 1). Over the 5-week running form modification program, we observed a trend of change in GRF over time ($p = 0.053$). In addition, there was a significant interaction between group and time ($p = 0.013$). The post-hoc analysis showed that within the external group, the GRF over time was significantly different ($p = 0.029$), specifically, there was a significant increase in GRF between Session 1B (immediately after instruction) and Session 3 (at the end of 4 weeks; $p = 0.043$). Further analysis showed that at Session 4 (1 week retention), there was a trend of external group exhibiting greater GRF when compared to the internal group (2.61 ± 0.22 vs. 2.28 ± 0.26, $p = 0.060$).

When investigating the trunk angle at the 2.5 m/s running speed, we found no significant statistical difference between the internal and external groups ($p = 0.179$; Figure 2). Over the 5-week modification program, we observed a significant general increase in trunk angle over time ($p = 0.015$). In addition, there was no significant interaction between group and time ($p = 0.257$). The post-hoc analysis showed that the trunk angle significantly increased after instruction when comparing Session 1A (pre-instruction) to Sessions 1B, Session 2, Session 3, and Session 4 (p = 0.028, 0.034, 0.029, and 0.031, respectively).

For the participants' self-selected running speed, we found no statistically significant difference between the internal and external groups for ($p = 0.302$, Figure 3). We also observed no significant change in speed over time ($p = 0.437$). We also observed no significant difference in GRF at the self-selected speed between the internal and external groups ($p = 0.314$; Figure 4). Over the 5-week modification program, we observed no significant change in GRF over time ($p = 0.48$). However, there was a significant interaction between group and time ($p = 0.008$). The post-hoc analysis showed that within the external group, the GRF over time showed a trend toward being statistically different ($p = 0.053$), specifically, there was a significant increase in GRF between Session 2 (2 weeks after training) and Session 4 (1 week retention; $p = 0.048$). Further analyses showed no significant difference between the internal and external groups at any given time point.

Finally, our results showed no significant difference between internal and external groups when comparing trunk angle at the self-selected running speeds ($p = 0.263$; Figure 5). Also, we observed no change in trunk angle over time ($p = 0.168$) and no significant interaction between group and time ($p = 0.414$)

DISCUSSION

The objective of this study was to examine the effects of internal vs external attentional focus cues on running form modification and retention over the 5-week program. Specifically, our study looked at differences in GRF and trunk angle at 2.5 m/s and a self-selected speed. Each group received instructions aimed at increasing the forward trunk lean angle and having the participants adopt a forefoot strike pattern. By training runners to adopt this running form, we hoped to see a decrease in vertical GRF and an increase in trunk angle.

When specifically looking at the changes in GRF of our subjects, we did not find any statistical significant difference when comparing the internal and external attentional focus groups for either 2.5 m/s or the self-selected speeds. When taking a closer look at the 2.5 m/s speed, there was a trend toward a significant difference in GRF over time. Specifically, there was a significant increase in GRF observed within the external attentional focus group, which goes against our hypothesis. This factor of GRF is important to note due to its relation to foot strike pattern, which has been shown to have an influence over the overall injury rates during running. Daoud et. al. compared 3 categories of strike patterns that are prevalent among distance runners: rearfoot strike (RFS), fore-foot strike (FFS), and midfoot strike (MFS). [10] They concluded that subjects who consistently use a rear-foot strike pattern have approximately two times higher overall injury rates versus habitual FFS runners. [10] Many studies have characterized the kinematics and kinetics of each foot strike pattern. First, a FFS is characterized by an "attenuated impact peak for the vertical GRF." Versus RFS, which is characterized by "a larger impact peak and an increased loading rate of the vertical

GRF." This evidence suggests RFS runners are at an increased risk of injury due to the increased GRF loading rate. [11]

When specifically comparing changes in trunk angle between the external and internal groups, running speeds of 2.5 m/s and a self-selected speed showed no statistically significant difference. However, an overall significant increase in trunk angle was observed over the 5 weeks of running modification for both groups at 2.5 m/s. This increase in trunk angle continued from Session 3 through 4, with no additional reinforcement of the attentional focus cues, which demonstrated that learning and retention occurred for both groups. This is important to note because this shows that simple instructions, whether the participant was given an internal or external attentional focus cue, can alter the posture of runners to have an increased trunk angle during stance phase of running. This increase in trunk angle may lead to a decrease in running related injuries due to its effect of reducing the knee extensor moment and load on the knee. Many studies have shown that minor changes in trunk orientation can have a significant influence on the mechanical demands of the lower extremity, specifically reducing the knee load during running. Teng and Powers found that a difference of 7.2 degrees of trunk flexion resulted in 23.3% lower energy absorption and 13.3% lower generation of knee extensors versus participants who ran with a more upright trunk posture. [4] This can be attributed to a more forward trunk lean bringing the body's center of mass (COM) more anteriorly, thus reducing the knee extensor moment. Teng and Powers suggested a strategy to reduce knee loading during running may be to increase the forward trunk lean, ultimately leading to a decrease in lower extremity injuries at the knee.

Additional differences between our study and other studies comparing an internal verses external attentional focus is that of the skill being performed and type of feedback. In a systematic review performed by Dr. Wulf, multiple skills were performed using the two different attentional focus cues. These included golf swing and putt, volleyball serve, soccer, football kicks, basketball free throw, throwing accuracy, piano, and gymnastics routine. [6] These skills require one form of motion, versus our study, which assesses a continuous movement pattern of running. For example, an athlete performing a basketball free throw is capable of taking one shot at a time and receiving additional cues before each subsequent shot. While running, a person must continuously run in order to analyze the pattern. This requires multiple minutes of observation and analysis before receiving the appropriate cueing and feedback. This leads into the second difference between this study and Wulf's systematic review. With each free throw performed by an athlete, there is instantaneous feedback of their performance. Our study did not provide the proper feedback in order to allow the participants to analyze their own performance and recognize if they had applied the running form cues properly.

The reason for the difference between our study and previous studies may be because explicit feedback of trunk angle and foot strike pattern were not provided. While the lack of feedback may be a limitation, it is also common for self-trained runners to not have access to postural feedback during running. Future studies should focus on what forms of postural and kinetic feedback is more appropriate to induce changes in running form.

There are several limitations that need to be taken into consideration when interpreting the results of this study. First, the sample size of this study is small. For this reason, these findings may not have proper statistical power. Second, while the instructions are standardized, runners may interpret the running cues in their own way and adjust their running form differently. Third, a running program or progression used to alter running form, as in Chirunning, is usually longer than 4 weeks. The time the participants were given to alter their running form may not have been long enough. Another interesting point to note is that of the variability in initial running form for each participant. It would be difficult to adopt an increased trunk angle during running if the subject was already running with a forward trunk angle posture. Further analysis and studies should be done looking at individuals with a more upright running posture in order for there to be more change seen with their running form.

CONCLUSION

Simple instruction, whether given through internal or external attentional focus cues, can help to alter a person's running form. This study found no difference in trunk angle or GRF when comparing internal and external attentional focus groups. There was also no significant difference between the internal and external groups when it came to learning and retaining a new running form. By increasing a person's trunk angle and adopting a forefoot strike pattern can help to reduce the risk of injury for runners. Future studies are needed in order to identifying which attentional focus, internal or external, will promote better learning retention of running form reeducation. These future studies need to incorporate clear and precise instruction to promote an appropriate internal or external attentional focus, and also include some type of feedback to the participants so they are aware of how they are altering their running form.

TABLES

Table 1. Time Points With Biomechanical Testing Sessions	
Session	**Time Points (total weeks)**
1A	Pre-Instruction (wk 0)
1B	Immediate Post-Instruction (wk 0)
2	2 Weeks Post-Instruction (wk 2)
3	4 Weeks Post-Instruction (wk 4)
4	1 Week Post Training/Retention (wk 5)

Table 2. Attentional Focus Cues	
External Attentional Focus	**Internal Attentional Focus**
Imagine a string pulling you forward	Lean your trunk forward
Land on the front part of your shoe	Land on the front part of your foot

Table 3. Subject Demographics *(mean +/- sd)*			
	External Focus Group	**Internal Focus Group**	**p-value**
Age (years)	28.4 ± 4.7	25.4 ± 2.2	0.234
Height (cm)	167.9 ± 7.2	168.9 ± 3.4	0.785
Mass (kg)	71.1 ± 9.8	66.8 ± 7.5	0.467
Years of Running	11.0 ± 9.3	7.2 ± 4.4	0.444
Runs per week	3.3 ± 0.6	3.8 ± 0.4	0.161
Distance per week (miles)	16.2 ± 10.9	9.1 ± 3.9	0.208

FIGURES

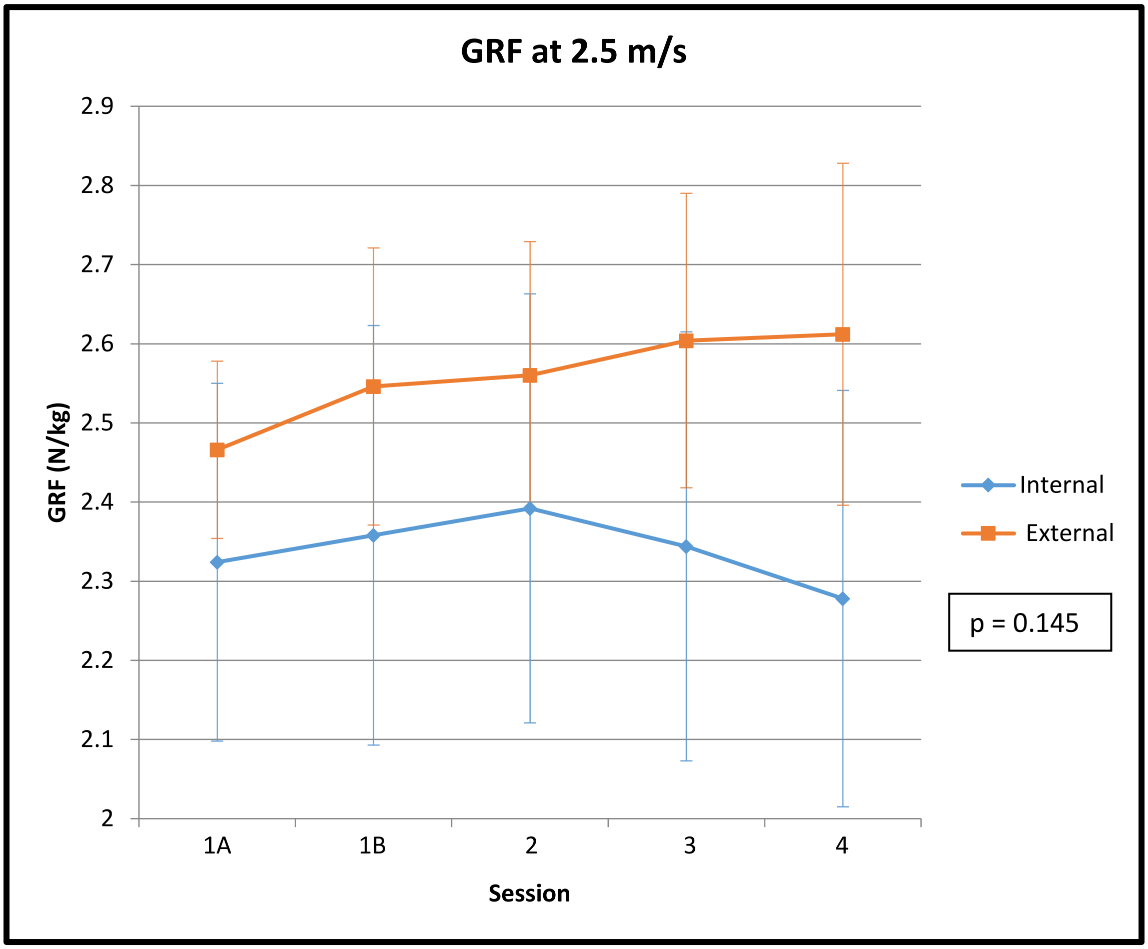

Figure 1. *Mean Ground Reaction Force (N/kg) across all conditions.*

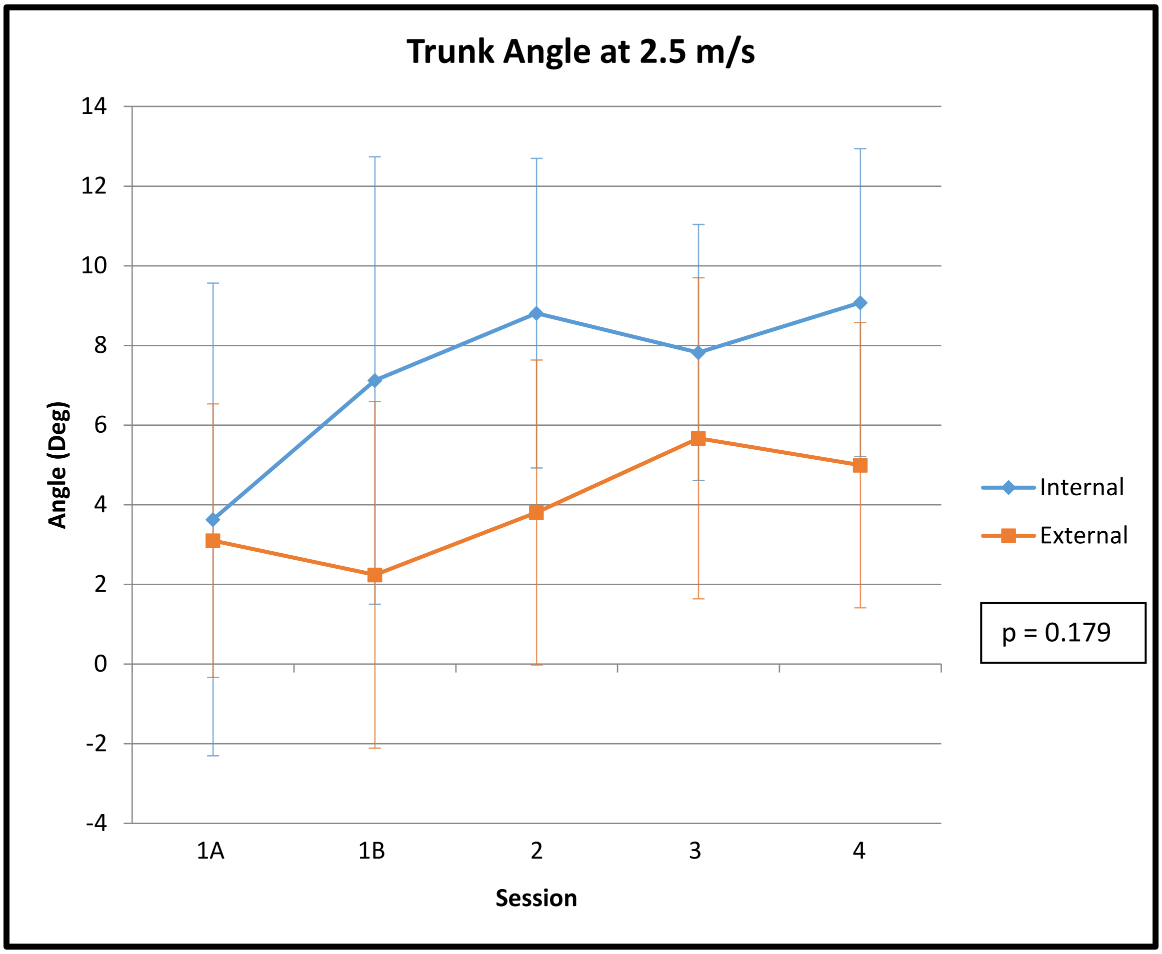

Figure 2. *Mean trunk angle (°) across all conditions.*

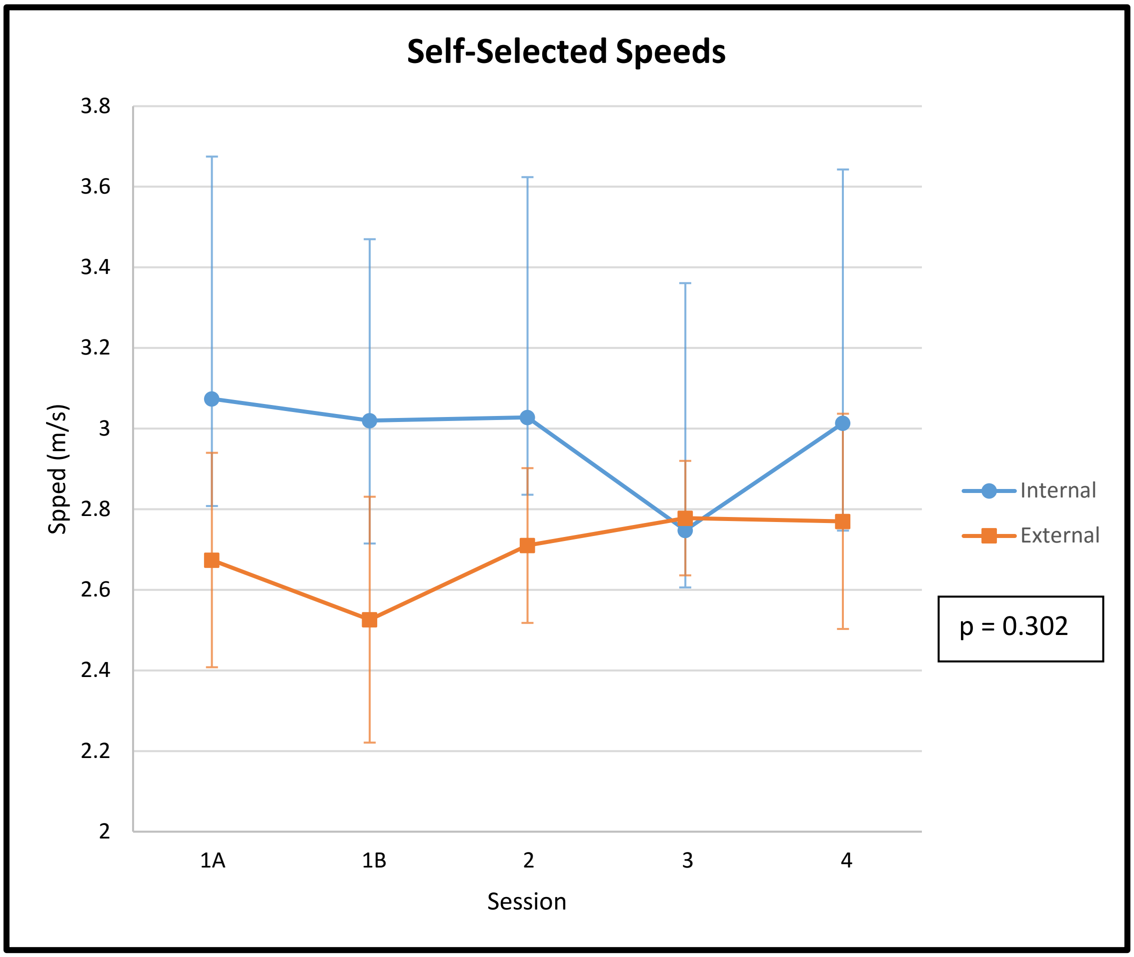

Figure 3. *Mean Self-Selected running speeds (m/s) across all conditions.*

Figure 4. *Mean Ground Reaction Force (N/kg) across all conditions.*

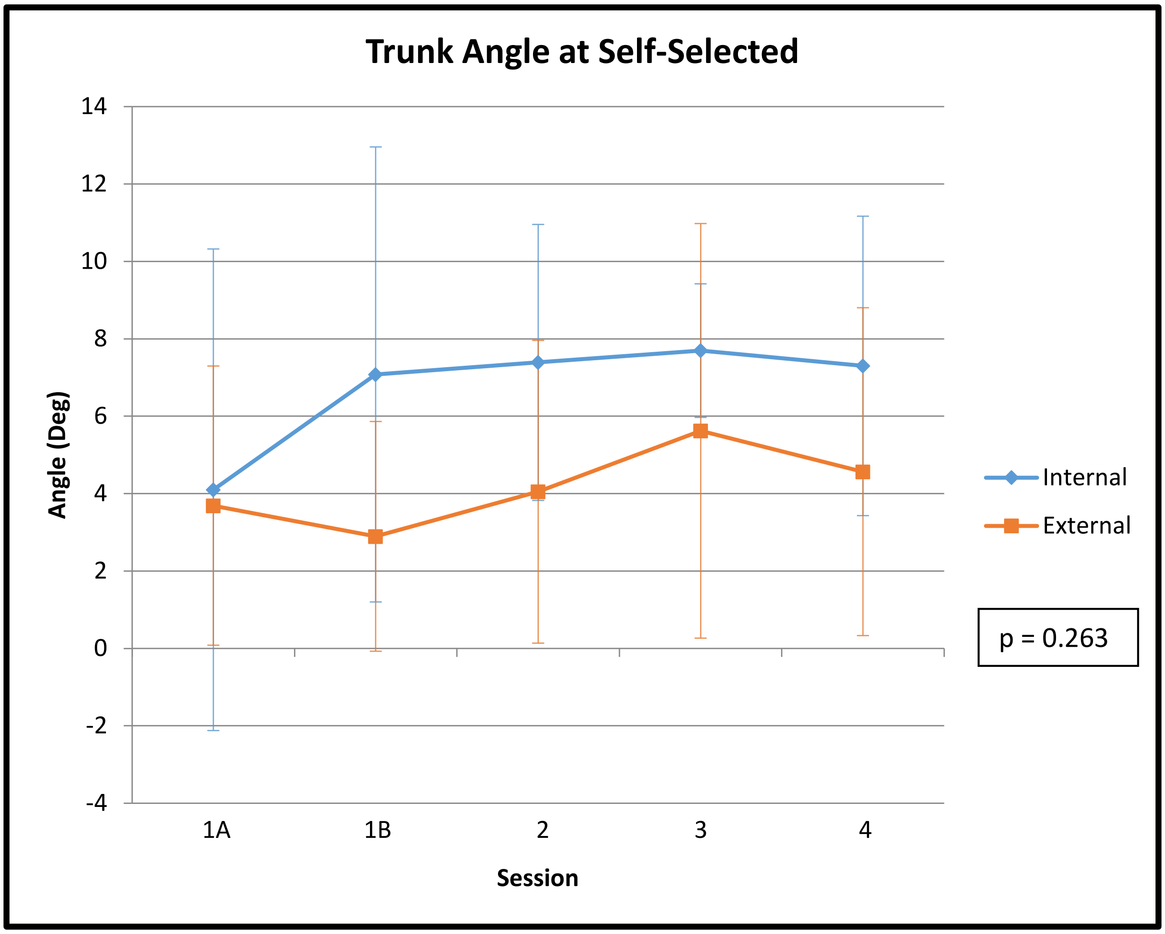

Figure 5. *Mean trunk angle (°) across all conditions.*

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Curriculum Vitae

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Education

University of Nevada, Las Vegas
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Clinical Experience

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10/05/2015- 12/16/2015

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Inpatient Rehab Intern
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Outpatient Orthopedic Intern
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Research

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Education

University of Nevada, Reno — Reno, Nevada
Bachelor of Science – Business Finance — May 2008
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University of Nevada, Las Vegas — Las Vegas, Nevada
Student in the Department of Physical Therapy — June 2013 – Present

Observation Hours

- 15 hours in a pediatric physical therapy setting
- 15 hours in a rehabilitation and neurological physical therapy setting
- 70 hours in an orthopedic physical therapy setting

Summary of Skills

Organizational Skills

- Organized monthly technology overview meetings
- Maintained database of institutional investors
- Compiled workout routines

Communication Skills

- Interacted with top tier investment banks and institutional investors
- Coordinated and facilitated communication between analysts and significant institutional shareholders
- Prepared material to showcase rental properties
- Arranged showings of rental properties with prospective renters

Management Skills

- Complete management of multiple rental properties including: negotiations, leasing, repairs and maintenance
- Supervisor of valet at a large hotel and casino

Helping Skills

- Coached baseball swing mechanics
- Aided in weightlifting and athletic training programs

Technical Skills

- Efficient in Word, Excel and PowerPoint

Work Experience

Valet Attendant, Mandalay Bay	May 2012 – June 2013
Server, Peppermill Resort Spa Casino	February 2010 – February 2011
Property Manager, DSKD Management	February 2009 – February 2010
Capital Markets Intern, Altair Nanotechnologies, Inc.	July 2008 – February 2009
Server, Chili's Bar and Grill Restaurant	July 2007 – September 2008
Valet Attendant/Supervisor, Atlantis Hotel Casino	February 2005 – August 2006

Professional Memberships

APTA	2013 – Present

Kenshin Scoggin, SPT

EDUCATION

- **University of Nevada, Las Vegas** – Las Vegas, NV – In progress
  - Doctor of Physical Therapy Degree Expected: May 2016
- **University of Oregon** – Eugene, OR
  - Bachelor of Science: Human Physiology
  - Minor of Business Administration
  - Graduated March 2011

PROFESSIONAL EXPERIENCE

Fyzical Sports Therapy, Las Vegas, NV · January 2016 – April 2016

- Outpatient Clinical Internship

Hale Anuenue Restorative Care Center, Hilo, HI · October 2015 – December 2015

- Rehab Clinical Internship

University Medical Center, Las Vegas, NV · July 2015 – September 2015

- Acute Care Clinical Internship

Matt Smith Physical Therapy, Las Vegas, NV · June 2014 – July 2014

- Outpatient Clinical Internship

RESEARCH EXPERIENCE

Mentored Group Research Project - In progress

- Student Investigator
  - Lee, S. Billington, E. Devries, S. Scoggins, K. Effects of Simple Postural Instructions on Running Form Modification in Recreational Runners-Preliminary Findings

PROGESSIONAL MEMBERSHIPS/CERTIFICATIONS

- APTA Member since May 2013
- Healthcare Provider CPR and AED Certification
  - American Heart Association
  - Expires: April 2016