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Effects of Four Years of Collegiate Sport Participation on Non-Contact, Contact, and Collision Athletes During Gait

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EFFECTS OF FOUR YEARS OF COLLEGIATE SPORT PARTICIPATION ON NON-CONTACT, CONTACT, AND COLLISION ATHLETES DURING GAIT

by

KRISTEN NEITZ

(Under the Direction of Barry Munkasy)

College athletes are often exposed to many training sessions, stresses, and injuries throughout their collegiate career. They often experience pain, stiffness, swelling, reduced range of motion and many other feelings following participation. Much research has focused on the acute effects of collegiate athletics, but the long term effect has not been well studied. Sports may be divided into groups based on the nature of play; the three main groups are non-contact, contact, and collision sports. Little research was found that examines differences between the three sport groups and their ability to complete activities of daily living such as walking following at least four years of college athletic participation. Purpose: To investigate differences in gait initiation and normal gait between non-contact, contact, and collision athletes after at least four years of college athletic participation. Methods: Eighteen participants completed 10 trials of walking down a pressurized instrumented walkway, at a self-selected pace prior to starting athletic participation in year 1 and following the last competition in year 4. The 10 trials were averaged and non-parametric tests were run to examine between group and within group differences. Results: Significant results within groups for gait initiation were found for the contact S2 M/L displacement ($p=0.028$); the non-contact S3 M/L displacement ($p=0.028$); contact S3 A/P velocity ($p=0.046$); non-contact S3 M/L velocity ($p=0.028$); and non-contact heel-to-heel base of support ($p=0.028$) after four years of collegiate athletics. Additionally, there were between group significance for baseline S2 M/L displacement ($p=0.011$); as well as post S3 M/L velocity ($p=0.032$) indicating a significant difference. No significant differences were found for variables within the S1 phase of gait initiation as well as the additional gait variables. Conclusion: The results of this study indicate that after four years of college athletic participation there was no significant change between baseline and post data for variables that would indicate instability. This suggests that after four years of participation that the injuries, training, and stresses occurring to the athletes is not having a significant effect on gait initiation or gait.

INDEX WORDS: Gait initiation, Gait

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DEDICATION

I would like to dedicate this project to all of my professors, advisors and classmates who helped to make this possible. As well as my family, without them I wouldn't be where I am today.

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CHAPTER 1

INTRODUCTION

Participating in collegiate athletics can have a series of effects on the athlete, many positive, but some negative. Collegiate athletes train on average five to five and a half days per week during their athletic season and 4.5-5 days during their off-season (Vetter & Symonds, 2010). Through frequent and intense training sessions athletes are left with limited time to fully recover from any physical stress placed on the body. Following athletic competition, athletes commonly report feelings of muscle soreness, stiffness, swelling, fatigue, loss of strength and reduced range of motion (Singh, Guelfi, Landers, Dawson, & Bishop, 2011). These feelings can make future practices more difficult to complete. Multiple practices on the same day may limit recovery for subsequent activities and may increase susceptibility to injury (Hootman et al., 2007). Injuries are often evaluated daily and most stresses are deemed 'recovered' if the athlete is continuing sport participation. Although it is important to understand the effects of these injuries day-to-day little is known about what long-term effects, if any, exist. Little research was found that examined the effects of injuries, training, and the daily stresses associated with athletic participation on the athlete's ability to complete activities of daily living following completion of an athletic career. Specifically, research has not focused on the possible changes in gait following at least four years of athletic participation. With the possible physical effects of sport participation on the athlete, examining these alterations among the various sports can be beneficial.

Sports are often divided into categories of non-contact, contact, and collision sports. Athletes who participate in collision and contact sports are subjected to impacts to the body that those in non-contact sports do not experience. The National Collegiate Athletic Association defines collision sports as those in which "athletes purposely hit other athletes or inanimate objects" (Klosner, 2013). Additionally, they define contact sports as those in which "the force and frequency of collisions, whether with other athletes or inanimate objects, are decreased." (Klosner, 2013) Currently there is no specific cutoff in frequency

and force that distinguishes between collision and contact sports. Noncontact sports are described as "those in which players do not come in contact with athletes or inanimate objects by force (Klosner, 2013)." When considering the varying nature of play among these sport types it can be expected that the injury rates may vary as well.

Approximately 12,500 injuries result in missed playing time in collegiate athletics every year (Thomas, 2017). When considering all male sports, football has the highest practice and injury game rate with 35.9 injuries per 1000 hours of athlete exposure; for female sports, women's soccer is the highest with 16.4 injuries per 1000 hours of athlete exposures (Hootman, Dick, & Agel, 2007). In a study examining 15 sports during multiple seasons, player to player contact accounted for the majority of injuries, with it being a cause of 41.6% of injuries during practices and 58% during games (Hootman et al., 2007). Despite many rules established to reduce the amount of dangerous contact with other players, it is reported that player contact is still one of the primary causes of injury (Hootman et al., 2007). For those participating in collision and contact sports there is an increased chance of direct player contact when compared to non-contact sports. More than half of the injuries that occur in contact sports involve the leg (Martin, 2007; Hootman et al., 2007). Studies consisting of NCAA Division I athletes reported that approximately 28% of injuries occurred at the ankle and 33% occurred at the knee (Westermann, Kerr, Wehr, & Amendola, 2016; Hunt et al., 2017). Of these injuries to the leg, ligamentous injury to the ankle is the most common (Hootman et al., 2007). Injuries to the leg often result in missed playing time and may result in a compensatory gait pattern during injury recovery.

Injury rates in collision and contact sports are considerably higher than those in non-contact sports and generally more severe due to the increase in impacts to the body (Kolata, 2017). Along with those impacts to the body come impacts specifically to the head. These head impacts can occasionally result in a concussion in which the athlete may experience many signs and symptoms associated with the cellular changes in the brain as a result of the hit (Broglio, 2014). It is also possible to receive multiple hits to the head or body that do not result in a concussive injury, these are referred to as repetitive head impacts

(Belanger, 2016). Repetitive head impacts may result in deficits similar to those associated with a concussion, but specifics have not been determined (Belanger, 2016). Examination of normal self-selected gait speed, of those with a concussion has revealed altered gait velocity, cadence, base of support width and double support percent (Williams, Morris, Schache, & McCrory, 2009).

An important step in understanding the effects of collegiate athletic participation on activities of daily living, specifically gait, is to examine an athlete's gait initiation and gait prior to initial collegiate athletic participation and then again at the completion of their collegiate athletic career. Gait initiation occurs during movement from a stationary double leg stance to the dynamic state of walking (Stansfield, Hawkins, Adams, & Church, 2018). A slower gait initiation time has been associated with physiological and cognitive impairments (Callisaya, Blizzard, Martin, & Srikanth, 2016). Gait initiation is made up of three phases, the anticipation phase (S1), transitional phase (S2) and locomotor phase (S3) (Buckley, 2017). The anticipatory phase is often referred to as the Anticipatory Postural Adjustment phase (APA) and is expressed as the initial shift in the center of pressure (COP) during gait initiation (Ebrahimabadi et al., 2018). The APA phase of gait initiation can often be impaired with neurological pathologies, such as Parkinson's disease (Ebrahimabadi et al., 2018). The S2 phase of gait initiation is identified as a lateral shift in the COP towards the stance limb. Lastly, the S3 phase is characterized by an anterior shift in the COP towards full ambulation. Gait initiation is often used as an assessment of the supra spinal motor control mechanism which controls gait initiation. (Ebrahimabadi et al., 2018). When examining gait initiation the changes in COP displacement and velocity occurring during each phase are calculated. Gait initiation is a highly stable task that can help identify alterations in dynamic postural control (Buckley, 2017). Changes in gait initiation have been noted in those with chronic ankle instability (Khanmohammadi, 2016). Examination of gait initiation can provide insight to possible alterations in dynamic postural control, which may allow researchers to effectively determine the presence of deficits, including those in the athletic population.

Gait analysis refers to the investigation of human locomotion to determine functionality as well as possible irregularities during gait (Akhtaruzzaman, Shafie, & Khan, 2016). Common spatiotemporal variables used to assess gait include: velocity, cadence, step and stride length, step width, and percent of single and double leg support. Velocity, width of base of support and double support phase can often indicate gait instability (Williams, Morris, Schache, & McCrory, 2009). Maintaining a normal gait pattern can lead to a more functionally sound human movement throughout daily life. Abnormal gait can be the main cause of many physical problems such as low back pain, joint pain, and possible muscle strain (Taga, 1995). Therefore, it is important to be aware and manage any abnormalities (Akhtaruzzaman et al., 2016). Analyzing gait initiation and gait can help to identify abnormalities after sport participation and allow for proper management in the hopes of eliminating future problems.

Research regarding gait and college athletics is scarce despite common injuries seen in an athletic population that may cause acute and chronic abnormalities when walking. An altered gait pattern has been noted in those returning from ACL reconstruction and these alterations can persist for longer than three months (Ferber, Osternig, Woollacott, Wasielewski, & Lee, 2002). Altered gait patterns may also expose the recovering athlete to a greater risk of early joint degeneration (Brian Noehren, Wilson, Miller, & Lattermann, 2013). Approximately four percent of injuries among collegiate athletes results in surgery (Kerr er al., 2015). Gait alterations have also been noted following the onset of osteoarthritis in those with patellofemoral pain syndrome and in those with iliotibial band syndrome (Ferber, 2010; Andriacchi & Mündermann, 2006; B. Noehren, Scholz, & Davis, 2010). It is clear that common injuries seen in an athletic population may cause acute as well as chronic walking abnormalities.

Due to the many factors influencing gait, it is not uncommon to see these abnormalities in a collegiate athletic population. Although many gait abnormalities may occur acutely following an injury, no research was found that examines what effect several years of collegiate athletic participation would have on an athlete's normal gait patterns. Furthermore, it is unknown which differences, if any, would present themselves when comparing those athletes competing in non-contact, contact, and collision sports.

Current research regarding collegiate athletics participation generally focuses on changes following one season of play, with deficits not always seen in such a short time (Murray et al., 2017; Vogelpohl et al., 2017; McAllister et al., 2012). Specifically, research has not focused on the possible changes in walking following at least four years of athletic participation. With the possible physical effects of sport participation on the athlete, examining these alterations among the various sports can be beneficial. Therefore, the purpose of this study was to investigate differences in gait initiation and normal gait between collision, contact, and non-contact athletes after at least four years of college athletic participation.

It was hypothesized that those who participated in non-contact, contact, and collision sports would present with a significant difference in COP velocity and displacement during gait initiation following at least four years of collegiate athletic participation. Additionally it was hypothesized that those three groups would present with significant differences for COP displacement and velocity at baseline data collection as well as the post data collection. When considering gait variables it was hypothesized that those who participated in non-contact, contact, and collision sports would present with significantly different gait patterns following at least four years of collegiate athletic population. It was also hypothesize that those three groups would present with a significantly different gait pattern at baseline data collection as well as at the post data collection.

CHAPTER 2

METHODS

Participants:

A total of 18 NCAA Division I athletes were recruited for this study, the number of participants was determined through the use of a power analysis. The participants were placed into one of three groups (collision, contact, or non-contact) dependent on the sport in which they compete. The collision sports consisted of football and soccer; the contact sports consisted of baseball, basketball, cheerleading, diving, and softball; and the non-contact sports included cross country, golf, rifle, swimming, tennis, volleyball, and track and field. The sport classifications were determined with the use of the NCAA Sports Medicine Handbook (Klosner, 2013). A minimum of six participants were included in each group to satisfy the power analysis. All participants participated for at least four years at the collegiate level in their respective sports prior to data collection. The participants were required to have completed baseline gait analysis testing (gait initiation and gait) prior to starting their first season of play. Prior to any data collection IRB approval was obtained and prior to sport participation the participants completed an informed consent.

Any participant who sustained an injury during their four years of athletic play, were included in the study if they were deemed fully recovered by the team physician and returned to play prior to data collection. Any participant who was not fully recovered, as assessed by the team physician, or had not returned to play were excluded from the study. Those participants who completed a fifth year of athletic play were also included in the study. Individuals were excluded if they any existing neurological disorders prior to sport participation or occurring during their participation that may have effect their normal giat mechanics.

Instrumentation:

Gait performance was assessed using a 7.9 m GAITRite Electronic Walkway (CIR Systems Inc, Franklin, NJ). GAITRite presents with ICCs between 0.91 and 0.99 (Webster, Wittwer, & Feller, 2005). The walkway has twenty-seven pressure sensors that collect real time data at a sampling frequency of 120 Hz. The GAITRite software (CIR systems Inc, Franklin, NJ) was used to collect spatial and temporal characteristics of gait for analysis. An AMTI OR6 Series Force Platform (1000 Hz, AMTI, Watertown, MA, USA) was used to obtain COP data during gait initiation for collection in conjunction with the Vicon Motion Capture System (Vicon Motion Ltd., Version 1.8.5, 120 Hz, Oxford, England).

Procedures:

The participants were tested within six to twelve months following the end of their last athletic season in their respected sports. Prior to data collection the participants completed a medical history questionnaire. The participants completed a total of ten trials of traditional normal walking down the instrumented walkway. Variables obtained for gait initiation were COP displacement and velocity in both the anterior/posterior (A/P) and medial/lateral (M/L) directions for phases S1, S2, and S3. Additionally, velocity, heel-to-heel base of support, and double support percent were obtained for gait measures.

The participants stood 1 m away from the start of the 7.9 m instrumented GAITRite walkway, on two adjacent AMTI force platforms. The participant was asked to walk at a normal, self-selected pace, and was told to walk like they do every day on the way to their classes. Data collection began directly prior to the participant being given the verbal cue to walk, following the cue the participant walked the full length of the GAITRite stopping 1 m past the end of the walkway, which was marked similarly to the starting location. The participant then turned around, data collection began again and when given a verbal cue, the participant walked back down the length of the GAITRite and stopped walking 1 m past the end of the walkway at the starting mark on the same two AMTI force platforms. The participant completed this task for five laps (five down and five back) for a total of ten passes down the length of the GAITRite to ensure an appropriate amount of trials were available for analysis.

Data Analysis

To accurately analyze gait initiation, it was crucial to ensure that there was no noise affecting the data. First a Fast Fourier Transformation (FFT) was run on the raw gait initiation data to determine if there was any unusual frequencies present. Results suggested that noise may have been present above 60 Hz during gait initiation. With that in mind, raw gait initiation data was low pass filtered at 60 Hz using MatLAB (MATLAB 2010, Mathworks INC., Natick. MA. USA). After filtering the data, COP was calculated using the following formulas: $COPx = (-My/Fz)$; $COPy = (Mx/Fz)$. The COP represents a weighted average of all the pressures over the surface of the area in contact with the ground. Fx, Fy, and Fz are the ground reaction forces in the M/L, A/P, and vertical directions. Mx and My are moments applied to the force plate that tend to either bend or rotate the force. Then using the filtered data the three phases of gait initiation: the S1, S2, and S3 phases were separated based upon two pre-determined landmarks, this can be seen in Figure 1. The COP displacement was calculated for each phase (Buckley, Oldham, Munkasy, & Evans, 2017). These calculations were done in both the A/P and M/L directions for each of the three phases.

The spatiotemporal characteristics for the ten-normal walking gait analysis trials were averaged to obtain one comprehensive score. The variables of interest for this study were determined based on previous research and include: velocity, heel-to-heel base of support, and double support percent of cycle (Williams, 2009). Velocity was obtained by dividing the distance traveled by the ambulation time and was expressed in cm/s. Heel-to-heel base of support was the heel center of the first footprint to the heel center of the last footprint and is measured in cm. The total double support was the period of time that both feet were on the floor, measured separately for each foot and is expressed as the percent of the gait cycle spent in double support (%).The variables were exported to Microsoft Excel (Microsoft Inc., Redmond, WA) for data analysis and labeled as "post" testing.

Statistical Analysis

Due to a small sample size, non-parametric testes were run using SPSS (Version 23.0, IBM Corporation, Armonk, NY) for analysis. This was to determine variations between the three groups at two different time points: baseline non-contact, contact, and collision as well as post non-contact, contact, and collision. A Kruskal Wallace test was run to assess between group differences during baseline and post data collection. This was completed for all variables: velocity, heel-to-heel base of support, double support percent, S1 displacement, S1 velocity, S2 displacement, S2 velocity, S3 displacement, S3 velocity. Additionally a non-parametric Wilcoxin test was run to assess within group differences for non-contact, contact, and collision from baseline to post for the above listed variables.

CHAPTER 3

RESULTS

Results:

The mean and standard deviation values for all gait initiation and gait measures along with data for all three groups, non-contact (NON), contact (CON), collision (COL) for both baseline (BASE) and post (POST) can be found in Tables 2 and 3, respectively. The results from the non-parametric tests examining within and between group comparisons can also be found in Table 2 and 3. Several results indicated statistical difference of $p<0.05$.

Gait Initiation

When examining gait initiation there was a significant decrease in M/L displacement during the S2 phase for the contact group from baseline to post (BASE = 17.78 ± 1.96 cm, POST = 13.72 ± 3.04 cm; p=0.028). There was also a significant increase in M/L displacement during the S3 phase for the non-contact group from baseline to post (BASE = 3.87 ± 3.47 cm, POST = 9.54 ± 3.95 cm; p=0.028). Additionally, there was significant decrease in A/P velocity in the S3 phase for the contact group (BASE = 0.33 ± 0.03 cm/s, POST = 0.27 ± 0.05 cm/s; p=0.046); as well as a significant increase in M/L velocity in the S3 phase for the non-contact group from baseline to post (BASE = 0.05 ± 0.04 cm/s, POST = 0.22 ± 0.10 cm/s; p=0.028).

When examining both the baseline and post data points there was significant differences between the three groups for displacement in the M/L direction within the S2 phase for the baseline time point (NON = 15.28 ± 3.84 cm, CON = 17.78 ± 1.96 cm, COL = 21.73 ± 2.97 cm; chi^2=9.064, p=0.011). There was also a significant difference among the groups when looking at velocity in the M/L direction during the S3 phase for the post time point (NON = 0.22 ± 0.10 cm/s, CON = 0.08 ± 0.05 cm/s, COL=0.18 ± 0.15 cm/s; chi^2=6.877, p=0.032). All other comparisons among the remaining gait initiation variables yielded no significant results.

Gait Parameters

When looking at the gait variables of interest, there was a significant increase in heel to heel base of support for the left foot within the non-contact group (BASE = 8.26 ± 3.16 cm, POST = 11.30 ± 5.40cm, *p*<0.028,). This was the only significant change noted among the gait variables.

CHAPTER 4

DISCUSSION

Discussion:

The purpose of this study was to investigate differences in gait initiation and normal gait between non-contact, contact, and collision athletes after four years of college athletic participation.

Gait Initiation: S1 Phase:

The S1 or the APA phase of gait initiation is expressed as the first shift in the COP when gait initiation occurs. Gait changes primarily in the APA phase of gait initiation occur following injuries, especially after a concussion. Following a concussion, gait initiation can be an effective measure of impaired postural control (Buckley, 2017). In a study by Buckley, 97.6% of the participants demonstrated a reduction in posterior displacement and velocity in the APA phase post-concussion (Buckley, 2017). Specifically, those with a concussion had a 5.5 cm decrease in COP displacement in the A/P direction, as well as a 2 cm decrease in COP displacement in the M/L direction (Buckley, 2017).

In regard to the current study, there was no significant change within or between the groups for the APA phase for either displacement or velocity measures. This suggests that despite the stresses, training, and injuries that occurred to these athletes throughout four years of athletic activity, there was no change in the APA phase as a result. With much research focusing on concussions interaction with the APA phase it is important to note that of the eighteen participants recruited for the study, 11 of them sustained at least one concussion during their time as a collegiate athlete. This suggests that any deficits present in the APA phase as a result of a concussion or other injury may eventually resolve itself. This could indicate that the APA phase may be more beneficial in detecting deficits acutely following a concussion rather than long term. The hypothesis regarding the change in COP in the collision and contact groups was not met. Further research should examine the specifics on recovery time within the S1

phase of gait initiation following a concussion as well as the longitudinal effects of injury to this phase. Examining the effects of training on the S1 phase of gait initiation may be beneficial as well.

Gait Initiation: S2 Phase:

The results of this study suggest that there is a significant decrease in the displacement during this phase for those participating in contact sports but not for those participating in collision or non-contact sports. This indicates that after four years of athletic participation, those participating in contact sports have a significant decrease in displacement during the S2 phase of gait initiation. Further results of the study suggest that there was a significant difference in the lateral displacement when comparing the three groups' baseline scores. This suggests that prior to starting athletic competition in the collegiate setting that the three groups presented with a significantly different lateral displacement when compared to each other. This could indicate that prior sport participation in the high school or recreational setting may have had an influence on these individuals' gait pattern. These same results were not seen at the post-athletic career time point.

Previous research examining the S2 phase of gait initiation has not revealed changes within this phase as a result of a specific mechanism. The significant findings found within the contact group after four years could be a result of certain training, injuries, or stresses that these athletes are exposed to compared to the collision and non-contact groups. The significant differences in displacement found at baseline again could be a result of the differences in training and injuries that occurred during high school athletic participation. The S2 phase of gait initiation is sensitive to the participant's initial stance position. A wider stance at gait initiation could result in an increase in S2 displacement, this may be why significant differences were noted within the S2 phase. Additionally, heel to heel base of support was run as a covariate and no significant interaction was found between heel to heel base of support and the S2 phase variables. Future research should control for the individuals initial stance position in the hopes of distinguishing any clinical interaction for this phase.

Gait Initiation: S3 Phase

The results suggest that after four years of participation, the non-contact group presents with an increase in M/L displacement during the S3 phase. Additionally, there was an increase in M/L velocity for this group and phase as well. The contact group also presented with significant results suggesting there was a decrease in velocity in the A/P direction after four years of athletic participation.

Previous research has not explored changes in either displacement or velocity in the S3 phase, nor what those changes could indicate. Often a decrease in velocity while walking can indicate instability, therefore it can be hypothesized that those with an increase in velocity may have presented as more stable and those with a decrease in velocity may have presented as less stable. The change in displacement could have been affected by the participants step length, explaining the increase in displacement seen. Previous research has indicated that foot length could also be a factor in S3 displacement and velocity. There does not appear to be any clinical significance for the changes seen and future research should attempt to control these factor to obtain more meaningful results.

Gait Parameters

As previously mentioned, the variables of interest for the normal gait portion of the study were velocity, heel-to-heel base of support and double support percent time. The results of this study suggest that there was a change in heel-to-heel base of support within the non-contact group following four years of athletic participation. Previous research has shown changes in walking velocity, heel to heel base of support, and double support time which could indicate instability (Williams, Morris, Schache, & McCrory, 2009). The results suggest that there is an increase in heel- to- heel base of support from baseline to post athletic career for those participating in non-contact sports. When considering previous research, it was expected that those results would have been seen in the contact and collision groups due to an increase in injury including concussions when compared to the non-contact group (Williams, et al., 2009). As previously mentioned, of the 18 participants recruited for the study, 11 of them had sustained a

concussion at some point during the four years. Of the six participants within the non-contact group, four had sustained one concussion and one of those four received more than one concussion during their time as a collegiate athlete. In summary, the changes within the non-contact group from baseline to post are possible but it was expected that a similar result would have developed within the contact and collision groups as well.

Comparisons

The results of this study revealed very little statistical significance. After examining the results further a few trends were found that may further guide future research. When considering gait baseline results, all of the variables were approaching statistical significance following four years of athletic participation those variables that were approaching significance were further more similar. This indicates that following four years of athletic participation those athletes in different groups presented more similarly while walking than they did at baseline. Additionally, during gait initiation a similar trend was found in the S1 phase A/P direction and the S2 phase M/L direction. The baseline results for those variables comparing the three groups was approaching significance but the data collected post athletic career were more similar. When examining the velocity data for gait initiation an opposite trend was found for the S1 M/L and S2 A/P results where following at least four years of collegiate athletic participation the groups began to approach significance when compared to the baseline data. Evaluating those variables that appear to be approaching statistical significance can be beneficial, had more participants been included in the study, those variables may have presented differently.

When examining those variables approaching significance understanding the individual specific demands of non-contact, contact, and collision sports is important. Breaking down the similarities and differences between these groups rather than just the amount of contact experienced may help to further understand the findings. Athletes in the collegiate setting are expected to complete a specific amount of practice hours while in season as well as during the off season (Vetter & Symonds, 2010). Despite sport

classification all collegiate athletes complete these hours which often consists of a certain amount of conditioning, weight lifting, as well as sport specific practices. Comparing collegiate sports to high school sports, collegiate athletes across the board may be getting a more consistent training experience with the inclusion of conditioning and lifting than they were in the high school setting, where sport specific training is often the only training occurring. With that being said this could explain the variations among the groups at baseline as well as the more similar results found following four years of collegiate participation. The NCAA implemented the 20/8 hour rule for all collegiate athletes; which mandates that while in season athletes can participate in training for a total of 20 hours per week and 8 hours per week during the off season (jcoram, 2013). As all collegiate athletes experience a more consistent amount of training time across the board, it may cause these athletes to present more similarly than they did prior to collegiate athletic participation.

While examining the similarities among the groups as a possible explanation for the results found it is also important to highlight the differences among the groups as well. The varying component was the sport specific practices. Sports within the non-contact group are generally more individual and require no contact with other athletes. Those in the collision group are constantly coming in contact with other players and objects and participate in more dynamic movements in which their stability is often challenged. Dynamic postural control is the ability to maintain the center of mass within the base of support while the body is subjected to internal or external perturbations that are anticipated or not (Sirois-Leclerc, Remaud, & Bilodeau, 2017). Collision sports often require more stability during play when compared to those in the non-contact group. When it comes to the testing measures of this study the daily demands of the sport could potentially influence the results. Considering the nature of play, collision athletes must maintain dynamic stability on a regular basis to compete in their sport may cause differences among the groups during data collection. It is unknown what specific effect the sport specific practices may have on gait initiation and gait variables, more research should be done to examine differences.

Head Impacts

As mentioned, those athletes participating in collision and contact sports are exposed to an increased risk of head impacts that can potentially result in a concussion. Research suggests that these athletes may experience cumulative effects of repetitive subconcussive impacts (Slobounov et al., 2017). A subconcussive impact is defined as an event similar to those giving rise to a concussion, but involving insufficient impact forces or accelerations to produce symptoms associated with a concussion (Shuttleworth-Edwards, Smith, & Radloff, 2008). Although the specific effects of repetitive head impacts are understudied it is a factor associated with participating in collision sports. Following one season of college football participation changes in brain structural/ functional or vascular integrity despite the lack of symptoms during the season occurs (Slobounov et al., 2017). With that being said it unknown whether these changes reflect compensatory adaptation to cumulative head impacts over a season, or more long-lasting or permanent alteration of brain health (Slobounov et al., 2017). When considering the results of this study, those participating in collision sport did not present with any statistically significant deficits in gait initiation nor gait variables following at least four years of college athletic participation. It is important to keep in mind that it is unknown if this indicates a lack of deficits as a result of repetitive subconcussive blows on gait measures.

Limitations

Any study comes with a series of limitations. More participants should be recruited in the future as including more participants could help make the results more meaningful. Limitations associated with the data collection process include the medical history questionnaire being self-reported. Future research may include injury surveillance to ensure accurate information is obtained. Additionally, baseline and post data collection sessions were conducted by different researchers. Although the same methods were followed during both sessions it is unknown what variations may exist as a result of different researchers.

A control group was not utilized as a comparison for this study but may provide meaningful information for future studies.

CHAPTER 5

CONCLUSION

The results of this study indicate that after four years of college athletic participation there was no significant change between baseline and post data for variables that would indicate instability. This suggests that after four years of college athletic participation that the injuries, training, and stresses are not having a significant effect on gait initiation or gait. Although unpredicted significant results were seen for some variables, future research should look to further explore the mechanisms affecting those variables. This research suggests that the athlete presents with no gait deficits following their last season of athletic play when compared to gait variables collected prior to collegiate athletic participation.

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APPENDIX A

LIMITATIONS

1. Medical history questionnaire was self-reported therefore.

2. Baseline testing was completed by a different group of researchers.

3. Athletes' activities during the off season were not taken into consideration.

4. Non-athletes were not used as a control group.

DELIMITATIONS

1. The study only looked at collegiate athletes from 1 University.

ASSUMPTIONS

1. It is assumed that self-reported medical history was accurate and trustworthy information.

2. It is also assumed that all retrospective data was collected appropriately and accurately.

HYPOTHESIS

It was hypothesized that those who participated in collision, contact, and non-contact sports would present with a significant difference in COP velocity and displacement during GI following four years of collegiate athletic participation. Additionally it was hypothesized that those three groups would present significant different for COP velocity and displacement at baseline data collection as well as post data collection. When considering gait variables it was hypothesized that those who participated in collision, contact, and non-contact sports would present with significantly different gait patterns following four years of collegiate athletic population. It was also hypothesize that those three groups would present with a significantly different gait pattern at baseline data collection as well as post data collection.

APPENDIX B: TABLES AND FIGURES

Table 1. Participant demographics per group: gender, height, weight, sport.

Sport Group	Gender	Height (cm)	Weight (kg)	Sport Participation
Non-contact	Male: 1 Female: 5	173.14±9.44	67.81±6.87	Swim: 2 Volleyball: 2 Track: 1 Rifle: 1
Contact	Male: 1 Female: 5	164.25±14.34	65.93±7.63	Cheer: 2 Baseball: 1 Softball: 2 Basketball: 1
Collision	Male: 4 Female: 2	183.73±7.85	98.13±23.65	Soccer: 3 Football: 3

Table 2. Means (standard deviation) of Gait Parameters for all Groups at Baseline and Post Athletic Career

| Variables | Baseline | | | | Post | | | | Baseline-Post P-Value | | |
	Non-Contact	Contact	Collision	*p-value*	Non-Contact	Contact	Collision	*p-value*	Non-Contact	Contact	Collision
Velocity (cm/sec)	126.40 (8.83)	135.99 (6.59)	126.07 (25.96)	0.085	128.68 (8.09)	134.45 (17.25)	128.25 (21.80)	0.093	0.249	0.753	0.600
HHBSupL (cm)	8.26 (3.16)	10.95 (3.66)	14.33 (4.55)	0.058	11.30 (5.40)	11.37 (3.87)	14.30 (5.15)	0.464	0.028*	0.463	0.753
HHBSupR (cm)	8.33 (3.11)	10.97 (3.50)	14.21 (4.48)	0.075	10.15 (3.63)	11.38 (3.72)	14.14 (5.07)	0.413	0.173	0.463	0.917
DoubSupL	22.96 (1.85)	20.29 (1.74)	22.92 (2.88)	0.070	23.15 (1.71)	21.60 (2.14)	22.50 (3.48)	0.696	0.686	0.345	0.345
DoubSupR	23.02 (1.74)	20.27 (1.83)	22.87 (2.90)	0.064	23.16 (1.70)	21.65 (2.15)	22.54 (3.53)	0.727	0.917	0.345	0.400

Note: Heel to heel base of support left (HHBSupL), heel to heel base of support right (HHBSupR), double support percent left (DoubSupL), double support percent right (DoubSupR).

Table 3. Means (standard deviation) of Gait Initiation Variables for all Groups at Baseline and Post Athletic Career

Variables	Baseline				Post				Baseline-Post P-Value		
	Non-Contact	Contact	Collision	*p-value*	Non-Contact	Contact	Collision	*p-value*	Non-Contact	Contact	Collision
DIS_S1_AP	3.48	2.47	3.69	0.064	2.86	2.23	3.81	0.203	0.600	0.463	0.753
	(1.62)	(0.95)	(1.80)		(1.77)	(1.02)	(1.76)				
DIS_S1_ML	3.87	3.28	5.19	0.240	3.90	3.08	4.39	0.372	0.917	0.753	0.345
	(0.87)	(1.96)	(2.12)		(1.76)	(1.50)	(1.52)				
DIS_S2_AP	1.41	0.61	2.59	0.119	1.27	1.73	2.78	0.402	0.753	0.116	0.463
	(0.93)	(2.02)	(1.24)		(1.03)	(2.71)	(1.90)				
DIS_S2_ML	15.28	17.78	21.73	0.011*	18.59	13.72	18.03	0.114	0.173	0.028*	0.116
	(3.84)	(1.96)	(2.97)		(5.83)	(3.04)	(8.18)				
DIS_S3_AP	13.93	15.06	15.16	0.676	13.31	15.02	12.62	0.459	0.600	0.917	0.249
	(2.91)	(2.91)	(3.38)		(1.55)	(3.40)	(5.86)				
DIS_S3_ML	3.87	4.27	6.73	0.700	9.54	4.37	6.84	0.113	0.028	0.753	0.917
	(3.47)	(4.91)	(6.38)		(3.95)	(3.22)	(6.50)				
VEL_S1_AP	0.18	0.15	0.16	0.983	0.10	0.11	0.19	0.158	0.116	0.249	0.463
	(0.12)	(0.05)	(0.07)		(0.05)	(0.06)	(0.11)				
VEL_S1_ML	0.20	0.20	0.24	0.519	0.13	0.13	0.22	0.095	0.116	0.116	0.753
	(0.07)	(0.08)	(0.11)		(0.05)	(0.06)	(0.05)				
VEL_S2_AP	0.05	0.07	0.08	0.548	0.05	0.09	0.10	0.090	0.463	0.463	0.753
	(0.04)	(0.06)	(0.05)		(0.04)	(0.02)	(0.08)				
VEL_S2_ML	0.50	0.65	0.64	0.421	0.66	0.49	0.59	0.700	0.345	0.116	0.463
	(0.11)	(0.22)	(0.17)		(0.26)	(0.17)	(0.20)				
VEL_S3_AP	0.24	0.33	0.33	0.421	0.31	0.27	0.31	0.692	0.173	0.046*	0.753
	(0.13)	(0.03)	(0.10)		(0.08)	(0.05)	(0.11)				
VEL_S3_ML	0.05	0.10	0.14	0.423	0.22	0.08	0.18	0.032*	0.028*	0.463	0.249
	(0.04)	(0.12)	(0.13)		(0.10)	(0.05)	(0.15)				

Note: This table displays displacement (DIS) and velocity (VEL) measures for the three phases in the anterior/posterior (A/P) and medial/lateral (M/L) directions.
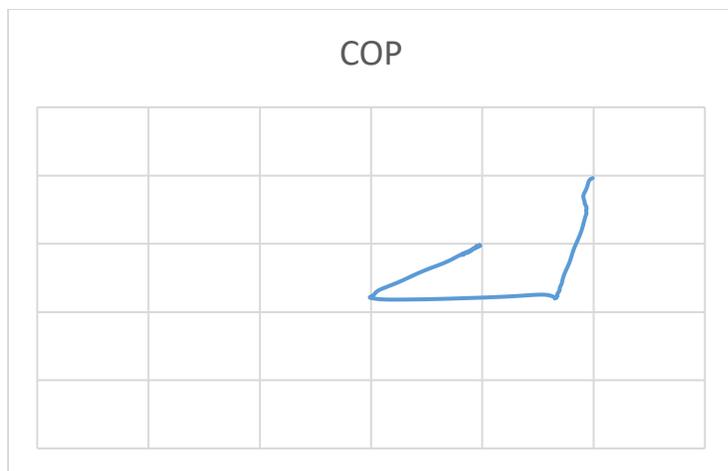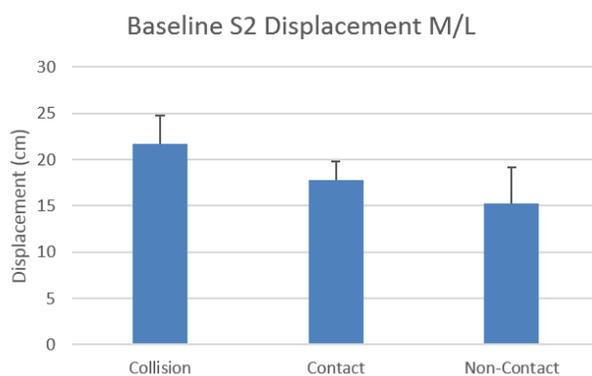
Figure 1: Gait Initiation pattern.

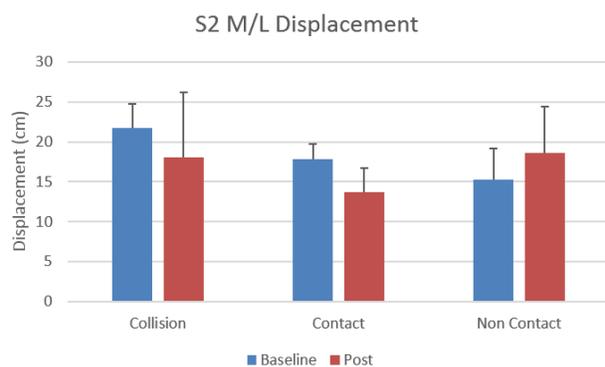Figure 2: Displacement M/L in the S2 phase at baseline. Significant differences found among the groups (p<0.011)

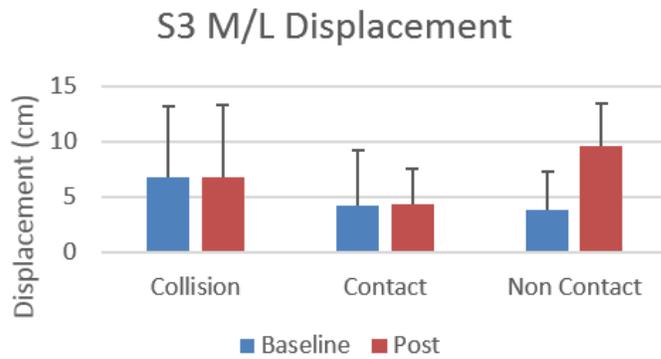Figure 3: Displacement M/L in the S2 phase. Significant differences for the contact group (p<0.028)

Figure 4: Displacement M/L in the S3 phase. Significant differences for the non-contact group (p,0.028).
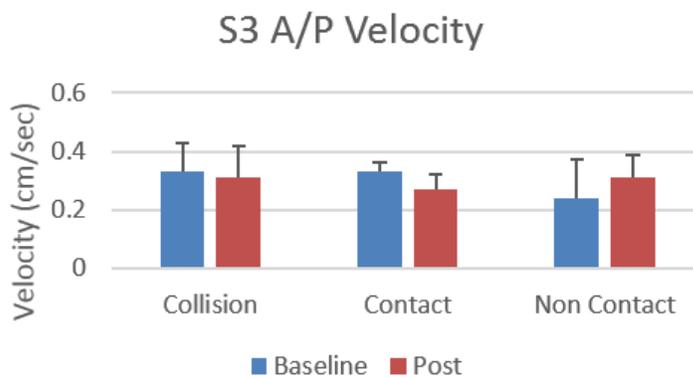

Figure 5: Velocity A/P in the S3 phase. Significant differences for the contact group (p<0.046).
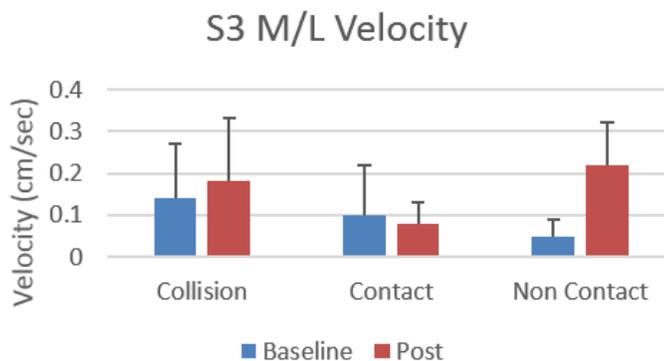

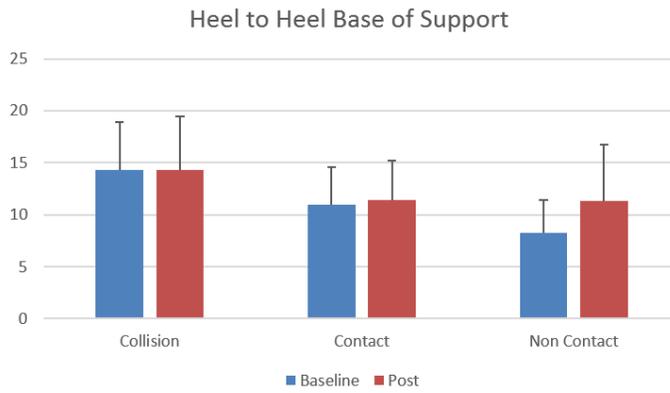Figure 6: Velocity M/L in the S3 phase. Significant differences for the non-contact group (p<0.028)

Figure 7: Heel to heel base of support. Significant results found within the non-contact group (p<0.028)

APPENDIX C: REVIEW OF LITERATURE

The health and wellness of those competing in collegiate athletics is a popular topic in today's society. Competing in sports at the elite level is a goal that many strive to achieve but the experience can be accompanied with a series of health risks and benefits. Athletes competing at this level are known for having high levels of fitness while also possessing impeccable physical power and strength (Sorenson et al., 2014). The physical advancements seen in these athletes is a result of daily practices, weekly games and many other workout sessions that push their body to perform. Researchers have been particularly interested in determining the optimal training program for athletes. This was attempted by manipulating intensity, frequency and volume in order to determine the training characteristics that result in the greatest strength gains for the athletes (Vetter & Symonds, 2010).

Participating in collegiate athletics can have a series of effects on the athlete, many considered positive, but some considered negative. Participating in collegiate sports can encourage better mental and physical health when compared to less active individuals (Downs & Ashton, 2011). Additionally, those who competed in Division I athletics presented with better psychosocial health, as well as better health-related quality of life during their post athletic career compared to their non-athlete counterparts (Sorenson et al., 2014). Participation in collegiate athletics can come with a series of risks. Athletes train on average around 5-5.5 days per week during their athletic season and 4.5-5 days during their off-season (Vetter & Symonds, 2010). Frequent and intense training sessions are typically required, leaving limited time to fully recover from the physical stress placed on the body. Continued increases in physical stress, such as preseason workouts, create an environment in which risk for injury increases. Once an injury occurs, common practices include restriction from play (Mann, Bryant, Johnstone, Ivey, &

Sayers, 2016). Following athletic competition, athletes commonly report feelings of muscle soreness, stiffness, swelling, fatigue, loss of strength and reduced range of motion (Singh, Guelfi, Landers, Dawson, & Bishop, 2011). Additionally, differences in physical stresses and occurrence of injury have been noted between athletes who participate in collision sports, contact sports and non-contact sports.

When considering injuries approximately 12,500 result in missed playing time in collegiate athletics every year (Thomas, 2017). When considering all male sports, football has the highest practice and injury game rate with 35.9 injuries per 1000 athlete exposure; for female sports, women's soccer is the highest with 16.4 injuries per 1000 athlete exposures (Hootman, Dick, & Agel, 2007). In a study observing 15 sports during multiple seasons it was reported that during both practices (41.6%) and games (58%), player to player contact accounted for the majority of injuries sustained (Hootman et al., 2007). Despite many rules established to reduce the amount of dangerous contact with other players, it is reported that player contact is still one of the number one causes of injury (Hootman et al., 2007). For those participating in collision and contact sports there is an increased chance of direct player contact when compared to non-contact sports. It is reported that more than half of the injuries that occur in contact sports involve the leg (Martin, 2007) (Hootman et al., 2007). Studies consisting of NCAA Division I athletes reported that approximately 28% of injuries occurred at the ankle and 33% occurred at the knee (Westermann, Kerr, Wehr, & Amendola, 2016) (Hunt et al., 2017). Of these injuries to the leg, ligamentous injury to the ankle is the most common (Hootman et al., 2007). Injuries to the leg often result in missed playing time and may result in a compensatory walking during injury recovery.

Sports are often broken into categories of collision, contact sports and non-contact sports. Athletes who participate in collision and contact sports are subjected to impacts that those in non-contact sports don't experience. A collision sport is defined as "an individual or team sports during which the participants use their bodies to deter or block opponents, thereby relying on the physical dominance of one athlete over another ("collision sport," n.d.); a contact sport is defined as "any sport in which physical contact between players is an accepted part of play" ("Contact sport | Define Contact sport at Dictionary.com," n.d.); and a non-contact sport is "a sport in which players are physically separated such as to make it nearly impossible for them to make physical contact during the course of a game." Sports classified as collision or contact consist of: football, soccer. Contact sports include: baseball, basketball, cheerleading, dividing, and softball. Non-contact sports are: cross country, golf, rifle, swimming, tennis, volleyball, and track and field ("Sports Contact Levels," n.d.). A study suggests that injury rates in contact sports are considerably higher than those in non-contact sports and are generally more severe (Kolata, 2017).

Injury rates in collision and contact sports are considerably higher than those in non-contact sports and are generally more severe due to the increase in impacts to the body (Kolata, 2017). Along with those impacts to the body comes impacts specifically to the head. These head impacts can occasionally result in a concussion in which the athlete may experience many signs and symptoms associated with the cellular changes in the brain as a result of the hit (Broglio, 2014). It is also possible to receive multiple hits to the head or body that do not result in a concussive injury, these are referred to as repetitive head impacts (Belanger, 2016). Research suggests that these repetitive head impacts may result in deficits similar to those associated with a concussion, but specifics have not been determined (Belanger, 2016). Although unsure of

specific changes that may occur due to concussion, examining walking patterns can still be helpful in narrowing down the possible abnormalities occurring. Research has shown that when walking at a normal self-selected speed, those with a concussion present with altered walking velocity, cadence, width of base of support and double support phase (Williams, Morris, Schache, & McCrory, 2009). Abnormal walking can be the main cause of many physical problems; therefore, it is important to be aware of any abnormalities. As previously mentioned, we are unsure what possible changes to walking may exist.

As previously mentioned, the highest rates of injury are said to occur in contact and collision sports ("Sports Injury Statistics | Johns Hopkins Medicine Health Library," n.d.). A study examining injury rates in college sports reported that football accounted for most of collegiate sport injuries each year (Kerr et al., 2015). Those who participate in contact sports experience an increase in muscle soreness and muscle damage following practices and competitions compared to non-contact athletes (Vetter & Symonds, 2010, Singh et al., 2011). Research suggests that around 12,500 injuries result in missed playing time in collegiate athletics every year (Thomas, 2017). When considering all male sports, football has the highest practice and injury game rate with 35.9 injuries per 1000 athlete exposure; for female sports, women's soccer is the highest with 16.4 injuries per 1000 athlete exposures (Hootman, Dick, & Agel, 2007). In a study observing 15 sports during multiple seasons it was reported that during both practices and games, player contact accounted for the majority of injuries sustained; player contact was the cause of injury 58% of the time during games, and 41.6% during practices (Hootman et al., 2007). Despite many rules established to reduce the amount of dangerous contact with other players, it is reported that player contact is still one of the number one causes

of injury (Hootman et al., 2007). For those participating in collision and contact sports there is an increased chance of direct player contact when compared to non-contact sports.

It is reported that more than half of the injuries that occur in contact sports involve the lower extremities (Martin, 2007) (Hootman et al., 2007). Studies consisting of NCAA Division I athletes reported that around 28% of injuries occurred at the ankle and around 33% occurred at the knee (Westermann, Kerr, Wehr, & Amendola, 2016)(Hunt et al., 2017). These injuries to the leg often result in missed playing time and can result in a compensatory gait pattern during the injury. Additionally, abnormal gait patterns can be seen in those recovering from surgery, other long term chronic injuries, as well as neurological injury stemming from concussion (Ferber, Osternig, Woollacott, Wasielewski, & Lee, 2002)(Andriacchi & Mündermann, 2006)(Noehren, Scholz, & Davis, 2010). Due to an increase in overall contact experienced, athletes in collision and contact sports have an increased chance of sustained impacts to the head as well as the rest of the body. Receiving repetitive head impacts throughout an athletic season can occasionally result in deficits similar to those of concussive injuries (Belanger, Vanderploeg, & McAllister, 2016).

Many studies have examined the possible effects of sustained multiple head impacts through the participation in collegiate sports ("College Sports–Related Injuries — United States, 2009–10 Through 2013–14 Academic Years," n.d.)(Belanger et al., 2016)(Broglio et al., 2014). The term, 'repetitive head impacts' (RHI) is a used to describe the hits that athletes repeatedly suffer throughout a competitive season. Studies have examined the long-term and short-term effects of these injuries in order to better understand the impact it has on the athletes body (Belanger et al., 2016) (Gajawelli et al., 2013). The repetitive head impacts occurring during performance in contact sports may not result in any outward symptoms indicating neurological

dysfunction despite the fact that neurological injury may be occurring (Bailes, Petraglia, Omalu, Nauman, & Talavage, 2013). Following a concussion, there is often an impaired interaction between the somatosensory, visual, and vestibular systems (Riemann & Guskiewicz, 2000). Deficits within the somatosensory system can result in an impairment in postural stability (Buckley, Oldham, & Caccese, 2016). Often postural control can be evaluated with tasks such as human ambulation, commonly referred to as human gait (Fino et al., 2018).

Gait assessments are generally performed on an instrumented walkway that gives specifics on normal gait measurements. Abnormal gait can be the main cause of many physical problems, therefore it is important to be aware and manage the abnormalities (Akhtaruzzaman et al., 2016). Maintaining a normal gait pattern will lead to more functionally sound human movement throughout daily life as well as during sports participation. Often these spatiotemporal characteristics can be abnormal due to many contributing factors. Some common problems stemming from abnormal gait consist of low back pain, joint pain and possible muscle strain (Taga, 1995). Ongoing gait abnormalities can eventually result in issues within the muscles, bones and nerves of the legs ("Walking Abnormalities," 2012). Analyzing normal walking can help to distinguish these abnormalities and allow for proper management in the hopes of eliminating future problems.

Gait analysis refers to the investigation of human locomotion in order to determine gait functionality as well as possible gait irregularities (Akhtaruzzaman, Shafie, & Khan, 2016). The human gait cycle starts with the heel-strike and ends when the opposite foot reaches heel-strike. The gait cycle is composed of various phases that enable the body to propel itself forward during walking. The human gait cycle is composed of a swing phase that accounts for 40% of the cycle and the stance phase which accounts for 60% of the cycle (Akhtaruzzaman, Shafie, & Khan,

2016). Often these two cycles are broken down further into sub-phases such as, initial contact, load response, mid stance, terminal stance, pre-swing, initial sing, mid-swing, and terminal swing(Tao, Liu, Zheng, & Feng, 2012). Common variables used to assess walking gait are referred to as spatiotemporal characteristics, these often consist of measures such as: velocity, cadence, step and stride length, step width, and percent of single and double leg support. In those with normal walking patterns, the average speed of walking is around 2.2km to 2.8km per hour, individuals also present with an average stride length of 70cm to 82cm, a stride width of about 7 to 9cm, an average of about 90 to 120 steps per minute and a gait cycle that takes around 0.8 seconds to 1.2 seconds (DeLisa, 1998). Although these are the average values seen, often individuals will display with abnormal walking patterns for various reasons.

Gait initiation (GI) is experienced during movement from a double leg stance to the dynamic state of walking (Stansfield, Hawkins, Adams, & Church, 2018). In comparison to normal walking, gait initiation can be a more sensitive measure of gait. Research has suggested that a slower gait initiation time can be associated with physiological and cognitive impairments (Callisaya, Blizzard, Martin, & Srikanth, 2016). Gait initiation is often used as an assessment of the supraspinal motor control mechanism which when altered can cause changes in gait initiation (Ebrahimabadi et al., 2018) (Buckley, Oldham, & Caccese, 2016). GI is considered a highly challenging task and requires the integration of multiple sensor information arising from somatosensory, vestibular and visual systems, along with the coordination of multiple skeletal muscles (Yiou, Caderby, Delafontaine, Fourcade, & Honeine, 2017).

Gait initiation is composed of three different phases, the anticipatory phase, the transitional phase, and the locomotor phase (Buckley, Oldham, Munkasy, & Evans, 2017). The anticipatory phase is the first phase, often referred to as the Anticipatory Postural Adjustment

(APA) phase and often presents with a posterior change in center of pressure (COP) (Buckley et al., 2017) (Ebrahimadbadi et al., 2018).The second phase, the transitional phase, is generally identified as a lateral movement towards the stance limb (Buckley et al., 2017). Lastly, the locomotor phase exhibits an anterior movement of the center of pressure forward in the direction of movement (Buckley et al., 2017). The phases are often distinguished by identifying three landmarks referred to as L1, L2, and L3 that mark the location of change in center of pressure. When examining gait initiation for possible changes the COP is often looked at, specifically the displacement and velocity occurring to the COP during each phase. When analyzing displacement and velocity of COP it should be examined in both the anterior/posterior (A/P) and mediolateral (M/L) directions.

Research has looked at the effects of concussions, chronic ankle instability, ankle osteoarthritis, initial forward lean, floor condition, carrying a load, and age on gait initiation (Khanmohammadi, Talebian, Hadian, Olyaei, & Bagheri, 2016)(Uemura et al., 2012)(Vieira, Sacco, Nora, Rosenbaum, & Costa, 2015)("Impact of prior concussions on health-related quality of life in collegiate athletes. - PubMed - NCBI," n.d.)(Fawver, Roper, Sarmento, & Hass, 2018). Currently, most research has focused on the APA phase which can often be impaired with neurological pathologies such as Parkinson's disease (Ebrahimabadi et al., 2018). Previous research has shown a significant reduction in displacement and velocity in those with concussions for both the posterior and lateral components of the anticipatory phase (Buckley, Oldham, Munkasy, & Evans, 2017). In a study looking at the effects of chronic ankle instability on gait initiation, the results suggested that COP displacement was reduced in the involved limb when compared to the uninvolved limb (Ebrahimabadi et al., 2018). Another study looking at ankle osteoarthritis suggested supraspinal motor control mechanisms may have changed in those

with posttraumatic ankle osteoarthritis (Wikstrom & Anderson, 2013). Although research has not been done on the effects of all injuries in regard to gait initiation it is possible that other injuries may have similar effects. Additional research has looked at the change in gait initiation for both barefoot and shod conditions and found that footwear does have an effect on center of pressure patterns (Vieira, Sacco, Nora, Rosenbaum, & Costa, 2015). As mentioned earlier, gait initiation research has examined age-related changes and found that when compared to a younger population the older population presented with a decrease in COP displacement and a lesser velocity during the APA phase in the AP direction and the locomotor phase in the AP and ML directions (Khanmohammadi, Talebian, Hadian, Olyaei, & Bagheri, 2016).

It is known that gait initiation is a complex task when compared to normal walking. Research suggests that it is a pre-programmed task that occurs automatically within the central nervous system. Although this is true, injury, various footwear, and age can all effect the normal pattern occurring during gait initiation. By observing the displacement and velocity of the center of pressure during the three phases of GI, researchers can gain insight into possible alterations occurring.

As mentioned, athletes are specifically exposed to many factors that can result in altered gait mechanics. Common factors such as pain, muscle weakness, nervous system diseases, lack of muscle tone, fractures, osteoarthritis, muscle injury or tear, and tendonitis are all factors that athletes are often exposed to (Kerkar, 2014). Immediately following injury athletes may present with an antalgic gait in which they try to avoid putting pressure on the limb experiencing pain (Tarulli, 2016). Antalgic gait can often occur following leg and foot trauma as well as more chronic conditions such as osteoarthritis (Lowth, 2014). Often an antalgic gait pattern will result in a shortened stance phase when walking as well as a slower gait cycle with shorter steps

(Lowth, 2014). Athletes can also present with a cautious gait pattern in which they walk very slow with a wide base and arms abducted to catch themselves in case of fall. This generally occurs in older individuals but can occur in those recovering from a previous fall, those with poor vision and often in those with a foot injury or abnormality (Lowth, 2014). A Trendelenburg gait pattern occurs when the individual walks and the body swings to the other side to compensate for hip drop on the affected side (Lowth, 2014). This can often occur in those with weak or overused abductors, gluteus maximus and gluteus minimus muscles. This gait pattern can also be seen in those suffering from L5 radiculopathy (Lowth, 2014). Athletes can also experience a waddling gait pattern due to proximal muscle weakness in the legs as well as during pubic symphysis diathesis (Lowth, 2014). This gait pattern will often result in a swaying walk and presents with a wide-based gait with toe walking. Research has also suggested that those suffering with psychiatric disorders may present with altered gait patterns. Those suffering from depression have noticeable parkinsonism which the individual takes shorter steps, reduces arm swinging as well as anteropulsion and retropulsion in which they walk with forward or backward acceleration (Lowth, 2014). Abnormal gait can also be caused by the manifestation of cerebellar disease in which the individual presents with ataxia (Lowth, 2014). Ataxia can be caused by genetic disorders, trauma, immune mechanism, and metabolic causes (Lowth, 2014). These individuals will often present with unsteadiness during gait, a wide base and highly impaired tandem gait (Lowth, 2014).

These abnormalities can occur for various reasons including biomechanical problems, injuries, fractures, neurological disorders and genetic disorders. These abnormalities can happen in many individuals across many age groups. Much research is centered around the abnormal gait patterns of the elderly population and the increase in fall risk associated with the issue

(Wolfson, Whipple, Amerman, & Tobin, 1990)(Verghese, Holtzer, Lipton, & Wang, 2009). Although the elderly is exposed to many of these risk factors so are younger populations, specifically those participating in collegiate athletics. Around 4% of injuries among collegiate athletes results in surgery for the athlete ("College Sports–Related Injuries — United States, 2009–10 Through 2013–14 Academic Years," n.d.). Little research has been done on gait and college athletics despite the fact that common injuries seen in an athletic population may cause acute and chronic abnormalities when walking. An altered gait pattern has been noted in those returning from ACL reconstruction and these alterations can persist for longer than 3 months (Ferber, Osternig, Woollacott, Wasielewski, & Lee, 2002). Altered gait patterns may also expose the recovering athlete to a greater risk of early joint degeneration (Brian Noehren, Wilson, Miller, & Lattermann, 2013). Approximately 4% of injuries among collegiate athletes results in surgery ("College Sports–Related Injuries — United States, 2009–10 Through 2013–14 Academic Years," n.d.). Gait alterations have also been noted following the initiation of osteoarthritis, in those with patellofemoral pain syndrome and in those with iliotibial band syndrome ("Competitive Female Runners with a History of Iliotibial Band Syndrome Demonstrate Atypical Hip and Knee Kinematics," 2010) (Andriacchi & Mündermann, 2006)(B. Noehren, Scholz, & Davis, 2010). It is clear that common injuries seen in an athletic population may cause acute as well as chronic walking abnormalities.

Due to the many factors influencing gait, it is not uncommon to see these abnormalities in a collegiate athletic population. Although many gait abnormalities may occur acutely following an injury, it is unknown what the effects of several years of collegiate athletic participation would have on an athlete's normal gait patterns. Furthermore, it is unknown which differences, if any, would present themselves when comparing those athletes competing in collision, contact

and non-contact sports. Current research regarding the effects of participating in collegiate athletics generally focuses on changes following one season of play and found that deficits are not always seen in such a short amount of time (Murray et al., 2017) (Vogelpohl et al., 2017) (McAllister et al., 2012). The long-term effects of sustaining daily impacts and injuries has not be observed, specifically in the area of gait analysis. Therefore, the purpose of this study is to examine the differences in velocity, double support time and base of support variables during normal walking between collision, contact, and non-contact athletes after four years of college athletic participation as well as changes in COP displacement during gait initiation to further distinguish the possible gait changes associated with collegiate athletic participation.

APPENDIX D: INFORMED CONSENT

CONSENT TO ACT AS A SUBJECT IN AN EXPERIMENTAL STUDY

Title of Project: Identification of Persistent Impairments in Postural Control Following Concussion

Investigator's Name: Barry Munkasy, Ph.D.   **Phone:** (912) 478-0985

Participant's Name: _____   **Date:** _____

Data Collection Location: Biomechanics Laboratory, Georgia Southern University Campus

2. We are attempting to compare the balance, coordination and bodily control of individuals who have suffered a concussion and compare that to people who have not suffered a concussion. There will be 500 participants in this study, about half whom and half who have not suffered a concussion. The results of this study will help athletic trainers in the evaluation, treatment, and return to play decision making process in individuals who have suffered a concussion.

3. You are being asked to participate in this study because you have recently suffered a concussion or are a control subject. Additionally, you have no history of any nerve, inner ear or balance disorders, metabolic disorders, or significant injury to the lower extremity. If you agree to participate in this study, you will be asked to attend testing sessions lasting 25 min. You will be tested post-concussion, your return to play day and then every 7 days over the next 2 months. During the session you will be asked to both stand still, on 2 feet and 1 foot, walk at normal pace while solving mental challenges and play the Wii Soccer game. During the session you will stand and walk across force platforms and a carpet which measures the forces you create on the ground. You will also stand on a Wii balance board that is on top of a force platform and wear a headset. Finally, we will record your performance on the balance, cognitive, and neuropsychological testing, and your self-reported symptoms that you complete as part of your normal post-concussion assessment. The balance test will be video recorded.

4. The information we collect on your performance may be sent off campus for analysis, however any information sent will be devoid of identifying characteristics (no one will be able to tell it's you). The video recordings will not be sent off-campus.

5. Your performance during these tasks will be compared to your performance during your baseline test, if you performed one, when you began playing sports at Georgia Southern University.

6. The risk assumed during the testing is no greater than you experience during your normal daily activities. There is minimal risk of physical injury or mental discomfort while performing

this experiment. There is a risk of falling during the gait and balance trials; therefore, a member of the research team will be in close proximity should you lose balance. The headset you will be wearing for the Wii Soccer game does not your impair vision and should sit comfortably on your head like a ball cap. If the headset becomes uncomfortable at any time, a member of the research team will immediately remove it. You understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided. You also understand that you are not waiving any rights that you may have against the University for injury resulting from negligence of the University or investigators. Should medical care be required, you may contact Health Services at (912) 478 – 5465.

7. You will likely receive no direct benefit for participating in this study, however you will be provided your results, once calculated, if you so request. The results of this study may be used to better understand and treat individuals who have suffered concussions.

8. You will attend testing sessions over the next 2 months lasting about 25 min.

9. You understand that all data concerning yourself will be kept confidential and available only upon your written request to Barry Munkasy, Ph.D. You understand that any information about your records will be handled in a confidential (private) manner consistent with medical records. Your identity on all records will be indicated by a case number. You will not be specifically mentioned in any publication of research results. However, in unusual cases your research records may be inspected by appropriate government agencies or released to an order from a court of law. All information and research records will be kept for a period of 5 years after the termination of this investigation. The video recordings will be retained for seven years as required by the Georgia Board of Regents policy.

10. If you have any questions about this research project, you may call Barry Munkasy at (912) 478-0985. If you have any questions or concerns about your rights as a research participant in this study it should be directed to the IRB Coordinator at the Office of Research Services and Sponsored Programs at (912) 478-5465.

11. You will not receive compensation for your participation in this project. You will be responsible for no additional costs for your participation in this project.

12. You understand that you do not have to participate in this project and your decision to participate is purely voluntary. At any time you can choose to end your participation by telling the primary investigator, Dr. Munkasy.

13. You understand that you may terminate participation in this study at any time without prejudice to future care or any possible reimbursement of expenses, compensation, employment status, or course grade except provided herein, and that owing to the scientific nature of the study, the investigator may in his/her absolute discretion terminate the procedures and/or investigation at any time.

14. You understand there is no deception involved in this project.

15. You certify you are 18 years of age or older and you have read the preceding information, or it has been read to you, and understand its contents. Any questions you have regarding the research have been, and will continue to be, answered by the investigators listed at the beginning of this consent form or at the phone numbers given (912) 478 – 0985.

16. You have been provided a copy of this form.

Title of Project: Identification of Persistent Impairments in Postural Control Following Concussion

Principal Investigator
Barry Munkasy, Ph.D.
0107D Hollis Building
(912) 478-0985
BMunkasy@Georgiasouthern.edu

I, the undersigned, verify that the above informed consent procedure has been followed

_____   _____

Participant Signature   Date

_____   _____

Investigator Signature   Date