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The Effect of Ball Handling and Neurocognitive Processing on Lower Extremity Injury Risk in Soccer

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THESIS PROPOSAL

I. PROBLEM STATEMENT

Starting from the first principle that an injury cannot occur without loading on the tissues, Scott and Winter proposed estimating loading at injury sites to test hypotheses about biomechanical risk factors including ground reaction forces, joint moments, and muscle forces[11]. A joint moment is defined as the tendency of a bony body segment to rotate around the joint center due to the perpendicular component of the ground reaction force. The ankle, knee, and hip joints confine their particular associated bones but allow a range of motion for them; these bones are subject to rotational forces. The forces and moments arise from body movements of individuals during sports, especially during sharp turns or accelerations. External applied joint loads that displace the normal alignment of a joint are first resisted by skeletal muscle activation to stabilize the joint during a dynamic movement. Complex movements and/or poor neuromuscular coordination can result in failure of skeletal muscle to completely stabilize the joint's alignment, consequently relying on ligaments' tension to compensate. Ligaments attach one bone to another and provide stabilization. The ligament tension restricts abnormal rotation of bony joints but may be overwhelmed by extreme bony rotation, resulting in ligament tear. Sports that involve high intensity running and rapid acceleration and deceleration place great amounts of stress on ligaments due to the high forces of impact that cause joint moments, rotating the involved bones to unhealthy positions. As a result, injuries ensue that strain or tear ligaments within the joints.

Change-of-direction (cutting) maneuvers are essential for successful participation and performance in many sports but are unfortunately associated with non-contact lower extremity injury[2]. Previous research has shown that more injuries have been reported in soccer than hockey, volleyball, basketball, and several others[18]. In soccer, a field player makes 727 ± 203 cuts (turns) per game; this high volume of maneuvers alone increases likelihood for injury[7].

Non-contact lower extremity injury is associated with specific biomechanical variables shown to increase risk of injury; these include ankle inversion moment, knee abduction moment, internal tibial rotation moment, and hip abduction moment[7, 9, 12, 16].

These non-contact lower extremity injuries that occur during soccer as a result of sudden changes in momentum pose a problem to be addressed clinically. Understanding the mechanism of ball-handling cutting maneuvers in comparison to normal running-to-cutting maneuvers will allow for precise focus of training for athletes to reduce the risk of such injuries.

II. OBJECTIVES

1. Determine how hip, knee, and ankle mechanics in cutting maneuvers are influenced by ball handling in soccer players.
2. Determine how neurocognitive visual processing ability relates to kinetic and kinematic differences between ball handling and non-ball handling conditions.

Introduction of a soccer ball to a player during dynamic running movements fundamentally distracts the ball handler and alters kinetics and kinematics of the lower extremities. Specific high-risk biomechanical variables mentioned previously will be investigated to analyze the relative injury risk of ball-handling to non-ball-handling conditions. While focused on ball control during cutting, a sport-dependent variation movement, a player will compensate lower extremity cutting technique to maintain control. Therefore, we hypothesize that ball-handling cutting maneuvers will display increased high-risk biomechanical variables compared to the non-ball-handling cutting condition.

III. LITERATURE REVIEW

Our previous work suggests that more non-contact lower extremity soccer injuries in U.S. high school athletes occur during ball-handling (offensive/dribbling) maneuvers when compared to defensive maneuvers. This observation of unequal distribution of injuries was the reason for our interest. From the 2014 High School Reporting Information Online injury surveillance database, the ankle (47%) and knee (25%) were the most common locations of injury when analyzing ball-handling injuries of the lower extremities (thigh and lower). Ligament damage accounted for 62% of the analyzed lower extremity non-contact soccer injuries (sprains, incomplete and complete tears), which is often observed in cutting injuries[12].

Our previous work also suggests that sport-dependent variations of upper-body positioning during run-to-cut maneuvers are presented as risk factors for non-contact anterior cruciate ligament injuries[3]. This is applied to the current study by suggesting that sport-specific movements, such as ball-handling in soccer, can alter lower extremity kinetics and increase risk of injury.

No previous research has been conducted elucidating the mechanics of ball-handling cutting maneuvers in soccer. By comparing ball-handling to non-ball-handling mechanics, we hope to uncover important differences in soccer-specific injury risk.

Studies that have focused on cutting maneuvers have found a significant increase in lower extremity loading during unanticipated cutting tasks compared to identical anticipated tasks[17]. Assessing the effect of anticipation is outside the scope of this initial study, so we intend to implement only anticipated movements.

Additionally, it's been found that neurocognitive function assessed by the ImPACT® neurocognitive test is correlated to neuromuscular control and incidence of anterior cruciate ligament injury[14]. The biomechanical factors that drive this relationship are unknown, which motivates us to investigate the relationship between joint mechanics and neurocognitive ability, specifically in visual processing. Therefore, we will assess neurocognitive function of subjects in addition to cutting and ball handling biomehanics. The ImPACT® test has been shown to be a reliable neurocognitive test battery and has been used in past studies in assessing concussions in athletes[8, 10]. It has been used in both healthy and concussed populations as a clinical standard of care within the clinic and on the athletic sideline.

IV. PROCEDURES

A. RESEARCH DESIGN

To eliminate the potential confounding differences between matched subjects that hindered previous case-control and prospective studies, we are using a within subject experimental study design where each subject serves as his/her own control. The neurocognitive-biomechanics relationship will be assessed through a correlational design. All subjects will make one visit to the Sports Biomechanics Laboratory at the Martha Morehouse Medical Plaza where all measurements will be taken.

B. SAMPLING APPROACH

A sample of individuals who play competitive soccer regularly will be chosen to perform the run-to-cut maneuvers and soccer-specific ball handling maneuvers. Prior to biomechanical testing, all subjects will complete the computerized ImPACT® assessment through a secure computer in the lab. We expect to utilize a maximum of 32 subjects to perform the running and cutting maneuvers as well as performing the same maneuvers while ball handling, all of which observed at three angles: 45°, 90°, and 135°. This range of angles encompasses the majority of change of direction movements performed in soccer. The number of subjects will most likely be less than 32 because of time constraints.

The running and cutting mechanics during ball handling (BH) and non-ball handling (NBH) conditions will be collected to determine the differences in lower extremity kinematics and loading that occur due to the introduction of controlling a soccer ball while running and cutting. Since each subject serves as his/her own control, this increases the power of the study and allows pairwise comparisons. With a sample size of 32 subjects, we have at least 80% power to detect an effect size of 0.50 standard deviation change based on a 2-sided paired t-test at a significance level of 0.05, which is an appropriate and clinically-relevant effect size based on previous data[5, 13].

All subjects involved in the study must meet the following inclusion/exclusion criteria:

INCLUSION:

- Over 18 years old and under 35 years old at time of assessment
- A score of 7 or higher on the Tegner Activity Scale
- A score of 12 or higher on the Marx Activity Scale
- Must have played on an organized, competitive soccer team within the last 2 months
- Be able to perform jogging, jumping, pivoting, and cutting maneuvers without pain within the past month

EXCLUSION:

- Prior hip, knee, ankle, or foot injury within the last 3 months
- Previous surgeries to either lower limb
- Previous ACL tear, other ligament tear, tendon tear, muscle tear, or meniscus tear in either lower limb
- Knowingly pregnant women
- Individuals with a body mass index (BMI) greater than 30

Women that are knowingly pregnant are excluded because of the changes in body weight, center of mass, ligamentous laxity, activity level, and trunk muscle morphology that normally occur during pregnancy. Due to the limitations of optical motion capture using reflective markers attached to the skin, potential participants with a BMI greater than 30 will be excluded due to unacceptably high skin motion artifact.

RECRUITMENT

Soccer players will be recruited primarily from the university community. We will post announcements at the recreational facilities where physically active individuals predominantly exercise, as well as soccer facilities. Flyers will be posted both electronically via email and our web site and on paper in physical activity centers to recruit potential subjects. They will include contact information and a link to the eligibility survey.

INSTITUTIONAL APPROVAL FROM ORRP | IRB APPROVAL

It should be noted that the IRB at The Ohio State University has approved this study, effective 4/8/2015.

Protocol Number 2015H0015

PLAN FOR PROJECT STALLMENT

If less than 32 volunteer subjects are accrued before September of 2015, subject recruitment will stop and the current number of subjects will be used in data analysis. The project will still be completed.

SCREENING

All flyers and advertisements will direct interested individuals to a secure online survey (operated through SurveyMonkey.com) where they can answer screening questions and provide their contact information. The survey will provide details of the time commitment and ask inclusion/exclusion questions including the Tegner Activity Rating and Marx Activity Scale surveys below[6, 15]. Subjects must have a score of 7 or higher to be considered eligible, as well as meet the other criteria stated above. Once eligibility has been verified, an appointment will be scheduled.

Tegner Activity Scale

Level 10	Competitive sports- soccer, football, rugby (national elite)
Level 9	Competitive sports- soccer, football, rugby (lower divisions), ice hockey, wrestling, gymnastics, basketball
Level 8	Competitive sports- racquetball or bandy, squash or badminton, track and field athletics (jumping, etc.), down-hill skiing
Level 7	Competitive sports- tennis, running, motorcars speedway, handball Recreational sports- soccer, football, rugby, bandy, ice hockey, basketball, squash, racquetball, running
Level 6	Recreational sports- tennis and badminton, handball, racquetball, down-hill skiing, jogging at least 5 times per week
Level 5	Work- heavy labor (construction, etc.) Competitive sports- cycling, cross-country skiing, Recreational sports- jogging on uneven ground at least twice weekly
Level 4	Work- moderately heavy labor (e.g. truck driving, etc.)
Level 3	Work- light labor (nursing, etc.)
Level 2	Work- light labor Walking on uneven ground possible, but impossible to back pack or hike
Level 1	Work- sedentary (secretarial, etc.)
Level 0	Sick leave or disability pension because of knee problems

MARX SCALE (ENGLISH VERSION)

Please indicate how often you performed each activity in your healthiest and most active state, in the past year. Kindly put a (☑) mark on the appropriate space after each item.

	Less than one time in a month	One time in a month	One time in a week	2 or 3 times in a week	4 or more times in a week
Running: running while playing a sport or jogging	0	1	2	3	4
Cutting: changing directions while running	0	1	2	3	4
Deceleration: coming to a quick stop while running	0	1	2	3	4
Pivoting: turning your body with your foot planted while playing sport; For example: skiing, skating, kicking, throwing, hitting a ball (golf, tennis, squash), etc.	0	1	2	3	4

C. MEASUREMENT/INSTRUMENTATION

This study will use a combination of motion analysis testing, electromyography (EMG) and force dynamometry. All tests have been validated in our previous research. Markered motion capture and inverse dynamics have been extensively validated by many researchers over the past 30 years for use in determining the motion of and forces acting on the human body[1]. We will use EMG to estimate and monitor the activations of the muscles within the lower extremities in addition to the core musculature. We will use an inverse dynamics approach to estimate dynamic biomechanical loading on the body during overground running and side cutting.

D. DETAILED STUDY PROCEDURES

RECRUITMENT

- Participants will be recruited primarily from the university club soccer teams by asking their leaders to distribute flyers electronically, and secondarily the rest of the university community. We will post announcements at the recreational facilities where physically active individuals predominantly exercise, as well as soccer facilities. Initial contact with potential participants will come once they respond to announcements posted electronically or in print.
- We will post flyers both electronically via email and our web site (u.osu.edu/osusportsbiomechanics) and on paper in physical activity centers to recruit potential subjects.
- All flyers, whether in electronic form or printed, will include contact information and a link to the eligibility survey.
- The Ohio State University Club Soccer teams each consist of at least 23 players, providing a substantial number of potential subjects to reach the sample size of 32.
- Descriptions of the study with contact information will also be posted on our web site.

SCREENING

- All flyers and advertisements will direct all interested individuals to a secure online survey (operated through SurveyMonkey.com) where they can answer screening questions and provide their contact information. The survey will provide details of the time commitment and ask inclusion/exclusion questions.
- Once eligibility has been verified, a visit to the laboratory will be scheduled. A blank consent form will be sent to the subject via e-mail to read before the initial test date upon request.

DURATION OF PATIENT PARTICIPATION

All subjects will be asked to participate in only one session lasting less than three hours.

ESTIMATED TIMETABLE OF DATA COLLECTION

Data collection began as soon as IRB approval was gained on 4/8/2015, and will continue until September 2015. This will allow ample time to analyze and write the final thesis with existing data.

TESTING PROCEDURE

Prior to testing: All subjects will be asked to bring shoes that they normally wear to play indoor (i.e., gym floor) soccer (i.e., no cleats). Male subjects will be instructed to wear briefs under their shorts, as opposed to boxers or boxer briefs. Female subjects will be instructed to wear a sports bra for testing. If subjects do not have proper attire, a freshly laundered pair of side-split running shorts or disposable swimming trunks will be available for them to use during testing.

Beginning of Testing Session

- Testing personnel will explain the use of motion capture and the ImPACT® neurocognitive assessment to subjects and will answer any remaining questions the subjects have after reading the consent form.
- Subjects will be consented.
- Subjects will complete the computerized ImPACT® assessment on a computer located in the lab. This test will span about 25 minutes and takes the subject through 6 tests within that time. These tests challenge word memory, design memory, reaction time, and impulse control. Composite scores of verbal memory, visual memory, visual motor speed, reaction time, and impulse control will be calculated from the ImPACT® clinical report on the computer after completion.
- The ImPACT® assessment is broadly used both in healthy and concussed populations, and more information can be found in the attached document in the "Other Files/ Comments" section of the IRB application.
- Below describes the 6 tests and the clinical data calculated after completion[4]:
  6 Tests:
  - *Module 1:* Word Discrimination: Evaluates attentional processes and verbal recognition memory utilizing a word discrimination paradigm.
  - *Module 2:* Design Memory: Evaluate attentional processes and visual recognition memory using a design discrimination paradigm.
  - *Module 3:* X's and O's: Measures visual memory as well as visual processing speed and consists of a visual memory paradigm with a distractor task that measures response speed.
  - *Module 4:* Symbol Matching: Evaluate visual processing speed, learning and memory.
  - *Module 5:* Color Match: Represents a choice reaction time task and also measures impulse control and response inhibition.
  - *Module 6:* Three-Letter Memory: Measures working memory and visual-motor response speed.
- Clinical Data Calculation: There are five ImPACT® Test scores calculated from the neuropsychological tests administered, and each is displayed graphically
  - *Composite 1: Verbal Memory Composite*
    This score is comprised of the average of the following scores:
    - Total memory percent correct
    - Symbol match (total correct hidden symbols)
    - Three letters (total percent of total letters correct)

    A higher score indicates better performance on the Verbal Memory Composite
  - *Composite 2: Visual Memory Composite*
    This score is comprised of the average of the following scores:

        - Design memory (total percent correct score)
        - X's and O's (total correct memory score)

        A higher score indicates better performance on the Visual Memory Composite

    - *Composite 3: Processing Speed Composite*

      This score is comprised of the average of the following scores:
        - X's and O's (total correct (interference))
        - Three-letters (average counted correctly)

        A higher score indicates better performance on the Processing Speed Composite

    - *Composite 4: Reaction Time Composite*

      This score is comprised of the average of the following scores:
        - X's and O's (average correct RT (interference))
        - Symbol Match (average correct RT/3)
        - Color Match (average correct RT)

        A lower score indicates better performance on the Reaction Time Composite

    - *Composite 5: Impulse Control Composite*

      This score is comprised of the average of the following scores:
        - X's and O's (total incorrect (interference))
        - Color Match (total commissions)

        A lower score indicates better performance on the Impulse Control Composite

    - *Total Symptom Composite*
        - This score represents the total for all 22 symptom descriptors. A lower score indicates fewer endorsed symptoms by the test-taker. This series of graphs allows direct comparison of test performance in these core areas across multiple testing sessions. The composite scores were constructed to provide summary information regarding different broad cognitive domains. Thus far, ImPACT's® studies have indicated the verbal memory, visual memory, processing speed, reaction time and symptom scores assist in making a determination between concussed and non-injured individuals.

- Measurements of the subject's height and weight and other anthropometric data will be taken.
- Tape will be used to cover any reflective material on the subject's clothing or shoes as required. Clothing may also be bunched/rolled up and taped to expose bony landmarks where reflective balls (i.e., markers) are to be placed.
- Reflective markers will be placed on the subject's skin using double-sided tape to capture the subject's motion. These will be placed on the feet, legs, waist, torso, arms, and head. This marker placement requires palpation of bony landmarks. Testing personnel will explain the palpations to be performed and ask permission before palpating.

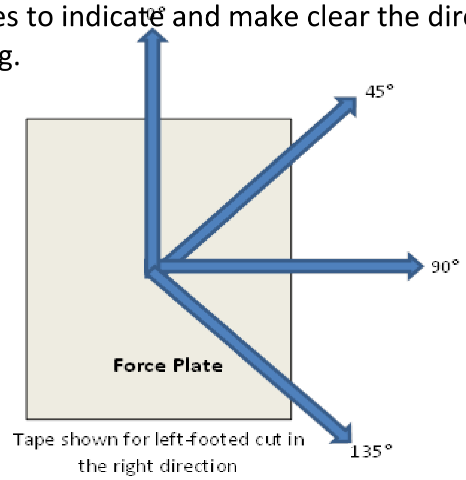
Demonstrating Maneuvers (Applies to Part 1 and Part 2)

- All testing personnel will be able to answer any questions that the participant has throughout the explanation and practice of the maneuvers.
- For each maneuver performed in the study, testing personnel will explain and demonstrate the maneuver to the participant, pointing out proper and improper maneuver technique. The participant will then be given the opportunity to practice the maneuvers to assure that she/he feels comfortable performing the maneuver for the study and understands how to do the maneuver safely.
- Throughout the performance of the maneuver during the study, study personnel will continually monitor the participant, giving feedback if the technique is correct or incorrect.
- If at any time the study personnel feel the participant is not performing the maneuver correctly and is unable to respond to corrective feedback, he/she will stop that maneuver bout and explain to the participant what is being done incorrectly. If the participant states that he/she cannot do what is being asked due to fatigue, discomfort or a lack of skill, the maneuver will be discontinued for the duration of the testing session.
- Before ball-handling trials, subjects will be encouraged to dribble with the ball to become comfortable and gain familiarity with the ball just as an athlete would before a game. They will be encouraged to dribble at a pace which they can run quickly yet maintain control of the ball throughout.

Motion Capture Testing:

Part 1: Maneuvers WITHOUT ball (Non-ball Handling)

- A tape intersection with lines at 0°, 45°, 90°, and 135° will be placed on the ground on the force plates to indicate and make clear the direction of cutting the subjects will be performing.



- Subjects will then perform a series of cutting maneuvers in separate trials. These involve the subject starting roughly 5 yards before the intersection, running forward at a self-selected speed, planting their contralateral foot (i.e., the foot opposite to the cut direction) near the intersection (point of direction change), and cutting in the specified direction.

- Subjects will perform the described cutting maneuver in 3 directions (i.e., 45°, 90°, and 135°).
- Subjects will only be asked to perform activities that they feel comfortable performing without pain or discomfort or fear of injury.

Part 2: Maneuvers WITH ball (Ball handling)

- The same subject will then perform the same series of cutting maneuvers, now while dribbling a soccer ball with their preferred dribbling foot. The side that contacts the ball corresponds to the side of cutting (i.e., right direction cut = right footed dribbling).
- The outside of the foot will be utilized to touch the ball in the correct direction as the other foot contacts the ground to perform the cut.
- Trials for each direction (i.e., 45°, 90°, and 135°) will be recorded on the same side.
- Subjects will use 3-5 trials to warm-up and become familiar with each condition, and 8 measured trials will be recorded per condition. This will assure a substantial number of usable trials when accounting for the variability in the conditions.
- Subjects will only be asked to perform activities that they feel comfortable performing without pain or discomfort or fear of injury.

DATA ANALYSIS

For assessing the effects of ball handling on lower extremity loads during cutting:

- Joint motions, forces, moments, and the forces generated in muscles will be calculated using commercial software (i.e., Vicon BodyBuilder) and custom software[1].
- The primary lower extremity biomechanical variables to be investigated are those we and others have previously identified as important variables for sports injuries including hip, knee, and ankle angles and moments[7, 9, 12, 16].
- Statistical Analysis
    - Each subject will serve as his/her own control, which increases the power of the study and allows pairwise comparisons on the effect of ball handling on lower extremity biomechanics.
    - Correlations will be calculated between neurocognitive function parameters and changes between corresponding ball-handling and non-ball-handling conditions for lower extremity biomechanics parameters.
    - All statistical analyses will be performed using commercial software (e.g., Microsoft Excel, MATLAB, or SPSS).
- Potential risks of participation
    - Discomfort/embarrassment of wearing clothes that expose the skin during motion testing
    - Discomfort associated with physical exertion no more than what is likely experienced during normal soccer training sessions

- Level of risk during motion capture and running biomechanics assessment is similar to the risk of injury during non-contact sports activities
- Methods for avoiding/minimizing risks
  - Adequate instructions and demonstration will be provided to the participants and only trained key personnel will be involved in participant testing.
  - All maneuvers will be supervised, and all supervisors will be trained as to appropriate maneuver technique to maintain safety.
  - No participant will be asked to perform an activity that he/she does not feel comfortable performing.
  - Only study personnel will be present during testing, and only study personnel will be permitted to view video images of testing to minimize the risk of undesired identification of subjects by other individuals.
  - A physician will be on call at the Sports Medicine Center to immediately attend to subjects in the case of any adverse events requiring medical attention, and the event will be handled in accordance with OSU Medical Center's policies.

FACILITIES & RESOURCES

All testing will occur in the OSU Sports Biomechanics Laboratory located at Martha Morehouse Medical Plaza, 2050 Kenny Road Columbus, 43221. Resources necessary include a motion capture system, retroreflective markers, skin tape, force plates, lab space, training cones, and a soccer ball.

V. REFERENCES

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