

IOWA

Technology Institute

Malum Terminus

*Simulation System for Injury Avoidance
("Limiting Injury")*

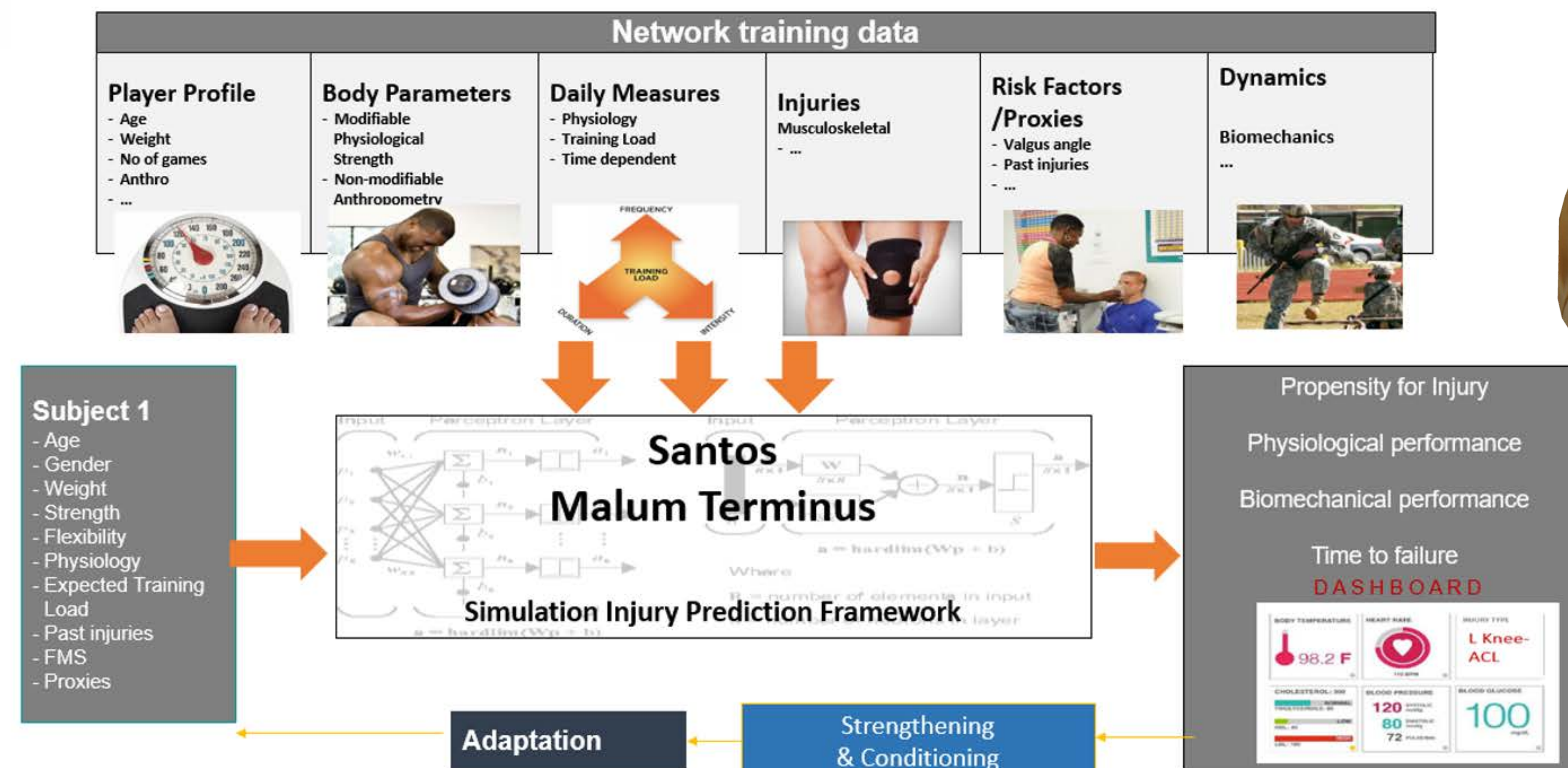
Malum Terminus Objectives

- The objective of this project was to develop a simulation platform for musculoskeletal injury (MSK-I) avoidance and prevention.
- Predicting injury rates, as well as predicting injury on an individual basis, was the ultimate objective of this effort.
- There are few, if any, sufficient modeling and simulation tools capable of addressing this issue. Physics-based models that allow one to study the mechanisms for injuries, make appropriate behavior modifications, and design effective treatment regiments are limited.
- Malum Terminus* is a framework for the development of a comprehensive platform to study and simulate MSK-I.
- The goal of the Malum Terminus system is to reduce the risk of injury, reduce costs due to injury, and provide scientific guidance on soldier-specific periodized strengthening and conditioning training in order to avoid injury and increase warfighter performance.

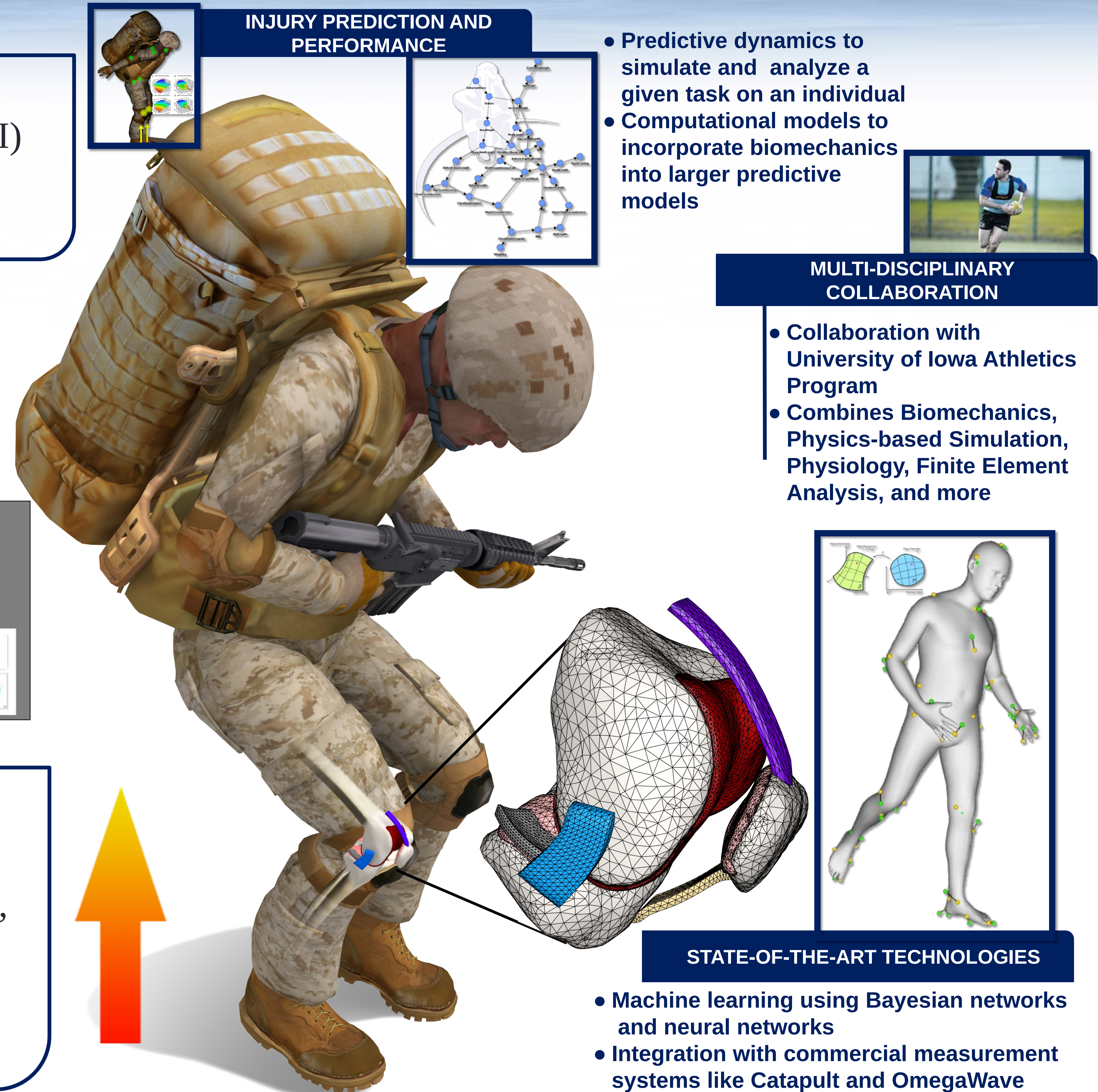
MALUM TERMINUS: A USMC simulation system for Injury Avoidance

Objective

To develop a simulation platform for understanding the mechanisms of Warfighter Musculoskeletal Injury (MSK-I) in order to reduce their occurrence and identify training interventions to enhance Warfighter performance.



MALUM is a human injury prediction tool based on AI, biomechanics, and sensory input. By monitoring Warfighter's training, stress and sleep levels, past injuries, and daily sensory data such as accelerometers, MALUM uses SANTOS and Deep Learning to predict and mitigate injury.



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Why Malum Terminus

- Musculoskeletal (MSK) injuries cost millions of dollars and lost-duty days annually and are arguably the leading medical problem eroding military readiness.
- The Marine Corps Recruit Depot (MCRD) in San Diego alone found that there were 53,000 lost training days related to MSK-I, which projected to a cost of \$16.5M.
- The specific problem of MSK-I has been identified as the single largest influence on cost and military readiness.
 - For example, data from a comprehensive military study in 2006 indicated that approximately 1.95 million MSK-I were reported across the entire military.
 - Most of these injuries (approximately 86.5%) are non-battle injuries.
- A recent study on evacuations from the Iraq/Afghanistan area of operation showed that one in seven evacuations were for musculoskeletal disorders, and the majority of these were for back and knee injuries.
- Another study predicted that the majority of non-battle injuries that required evacuation early in the conflict were musculoskeletal in origin and related to preexisting conditions

Malum Terminus Injury Model

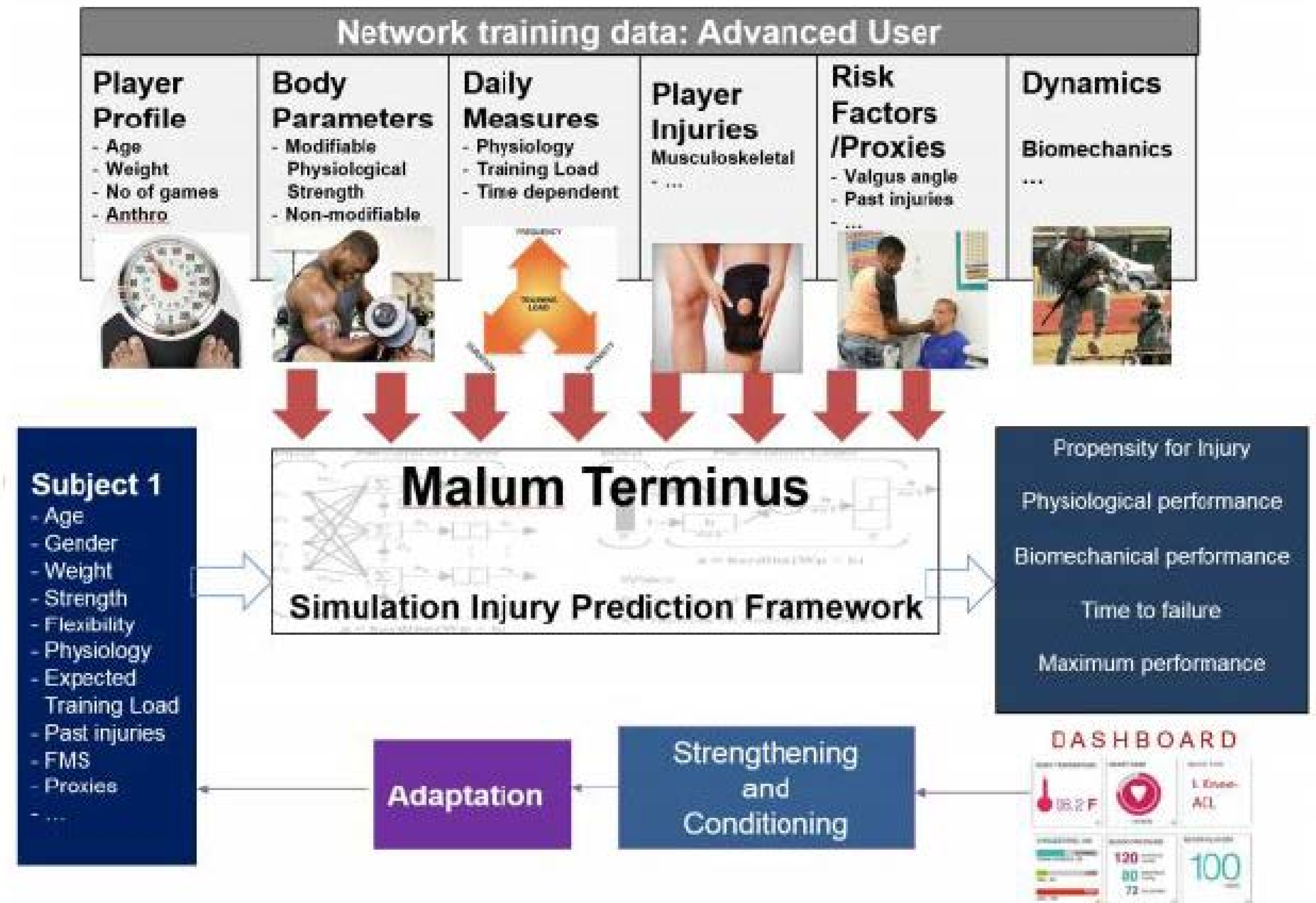
- Malum Terminus was developed as an individualized injury modeling architecture (and associated simulation environment) that considers many influencing factors, both physiological and biomechanical.
- A major difference between Malum Terminus and all previous methods is that it includes biomechanics as well as temporal tracking and cumulative modeling. The time history of effects of physiology/sleep/fatigue/training load combination on injury are significant factors in predicting MSK-I.
- Multiple independent technical solutions were developed to assist injury prediction by the Malum Terminus architecture. These include:
 - 1) automatic motion identification from inertial measurement unit (IMU) sensor data,
 - 2) a biomechanical efficiency metric based on IMU sensor data, and
 - 3) spatial posture and motion identification (SPMI).

Malum Terminus Injury Model vs Others

- There are several methodologies used by clinicians, athletic trainers, physical therapists, strength and conditioning coaches, and others to evaluate athletes. One such method used by clinicians is well documented by Rothstein and Echtertnach
- Another significant factor that has been considered in injury prediction is training load. Practitioners have been able to successfully employ objective and subjective measurements to help understand risk and mitigate subsequent injury when utilizing an acute chronic workload ratio.
- While all these studies provide a good starting point for a model, the VSR team discovered that performing post-event analysis is not good enough and that injury is not just about player load, but a combination of multiple factors.

Malum Terminus Injury Model Architecture

- Iowa developed a new approach based on an artificial neural network and a substantial amount of data, including biomechanics (as shown below)
- The model includes not only low-frequency, subject-specific data such as age, gender, height, weight, injury history, and strength information, but also high-frequency, sensor-based data such as daily player load, IMU sensor data, wellness questionnaire responses, and biomechanics. The goal is to eventually create a high-frequency injury prediction network to predict the likelihood that a specific motion of an athlete will result in injury by combining knowledge learned in independent team networks



Parameters and Metrics Tracked

- Gender
- Anthropometrics: Height (one time), weight (weekly or biweekly).
- Injury Data (MSK, Type, Date, location, type, grade)
- Injury history (self reported most of the time per student-athlete to ATC and Physician)
- Medical history: Allergies, pathologies, etc
- Current medication
- RPE Load

- Wellness Questionnaire (composite score)
 - Nutrition
 - Stress
 - Academic Intensity
 - Sleep Quality
 - Sleep Duration
 - Fatigue

- Training Load (load data)
 - Player Load
 - Distance (if outside)
 - Total IMA
 - Player Load/Minute
 - IMA Jump count (low, med, high threshold)
 - IMA Decel count (low, med, high threshold)
 - IMA Accel count (low, med, high threshold)
 - IMA CoD right count (low, med, high threshold)
 - IMA CoD left count (low, med, high threshold)

- Santos
 - Task Identified Acceleration Count

- Physiological tracking and readiness)
 - Omegawave
 - Overall Readiness
 - Strength Readiness
 - Speed and Power Readiness
 - Skill Work Readiness
 - Endurance Readiness
 - Cardiac Readiness
 - CNS Readiness
 - Omega Base
 - Volume adaptation
 - Tiredness Grade
 - Stress Index Grade
 - Reserves Grade
 - Recovery Pattern
 - Maximum Training HR
 - Anerobic HR
 - HR
 - SNS
 - PNS
 - RMSSD
 - Ti
 - MRI

Biomechanics Metrics

- No kinematic data during or prior to injury
- No kinetic data during or prior to injury
- Injury specific metrics are unavailable

Possible Performance

1. 10, 20, 30 yd or m sprint
2. Agility drills (5-10-5)
3. Countermovement jump
4. Squat jump
5. Standing long jump
6. Standing triple jump
7. Reactive Strength Index (jumping test)
8. Maximal strength testing (most teams, back squat)
9. Barbell velocity tracking -olympic lifts (power cleans, etc.
10. Intermittent aerobic testing
11. RSA (repeat sprint ability testing)



Findings



Example findings

Findings Case II

1. Simulation results indicate a **strong correlation** (strongest) between MSK injuries and **sleep duration** the night before injury.
2. Simulation results indicate a **somewhat strong correlation** between MSK injuries and **stress** (subjective score of 1-5) two days before injury.
3. Simulation results indicate a **somewhat strong correlation** between MSK injuries and **distance** covered the day before injury.
4. Athletes with MSK injuries are related to **the temporal tracking** of their performance, physiology, cognitive and biomechanics.

Findings Case I

- Expanded Metrics could **accurately predict injury 37.5%** of the time
 - Example for using Temporal Network: Expanded metrics w/o forbidden arcs predict injury 75%
- High RPE(chronic) + Low PL(chronic) = 13.55% chance of Injury
- **High RPE(chronic) + Low PL(chronic) + High PL(acute) = 99.59% chance of injury**
 - Reveals symptoms of Overtraining to put individual at state of emergency.
Combine state with hard work week = 99.59% chance of injury

Major Findings



Major Findings

Conclusions:

- ❑ Identification of kinematics and kinetics from IMU sensory data is plausible.
- ❑ Temporal tracking and **cumulative modeling** is essential. Time changes in physiological/sleep/fatigue/training load combination are significant factors.
- ❑ It is not only about player load...injuries occur because of a combination of factors that are substantially more significant
- ❑ MALUM TERMINUS, an injury-specific prediction model incorporating AI, simulation, and data collection, has **enormous potential** but is only scratching the surface.

Next Steps



Next steps

1. Collect more data to expand the “Deep Learning Identification” algorithm to include large number of team and more tasks
2. Integrate the biomechanical metrics into the prediction
3. Create additional metrics that specifically look at relationship between RPE:PL ratio
4. Must include sleep monitoring on athletes/military
5. Advance the Predictive Dynamics algorithm to include more tasks
6. Expand the model to additional MSK injuries
7. Work with others to define limits of deformation of tissue/classical biomechanics influence on metrics causing injury.

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