External Load Monitoring
Through Wearable Technology

GPS, Accelerometry, and Inertial Measurement Units

Dr. Jay A. Campbell
University of Oklahoma
Department of Health and Exercise Science
Sport and Tactical Performance Analytics Laboratory

My progression here….

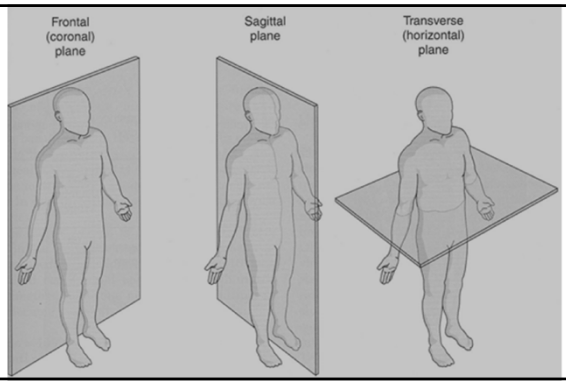
Starts with losing a job….

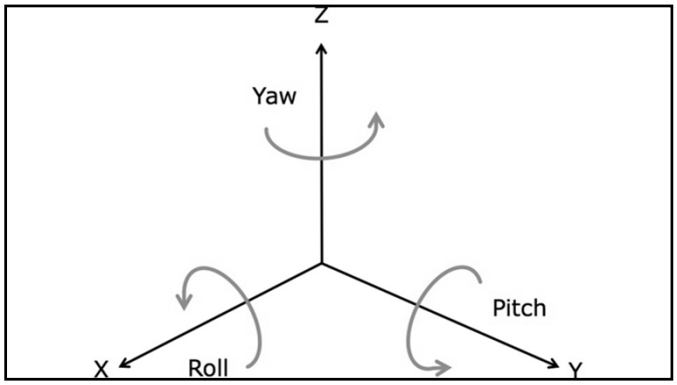
Global Positioning System (GPS)
Global Navigation Satellite System* (GNSS)

*Includes Russian GLONASS… May soon include European Union's Galileo and China's Beidou

Ultimately, these devices are "integrated microtechnologies"

- GPS/GNSS → Position
- Accelerometer → G-forces/Acceleration (3 planes of motion)
- Gyroscope → Rotations (3 axes – roll, pitch, yaw)
- Magnetometer → Orientation/Direction (outside monitoring)





RIP…. Goose

☹

Brief history of GPS…

- GPS navigation uses atomic clocks to determine the length of time it takes a radio signal to travel from a satellite to the GPS receiver on Earth
- At least 4 satellites are needed to "triangulate" a signal
- Since signal travel time can be measured, distance can be accurately measured
  - This allows us to determine the rate of displacement of a receiver over a given epoch
  - Thus we can determine velocity from this displacement and time elapsed between position changes

Brief history of GPS…

- **GPSports Systems (SP-10) was first sport application based system (2003)**
  - Validation study showed a systematic overestimation of 5% for distance
- **Next attempt at GPS validity wasn't conducted until 2009-2010**
  - Difficulty is with gold standard used for validation
  - Trundle wheel or tape measure is used to measure a course then timing gates are used to measure velocity
  - Problems:
    - Does the trundle wheel accurately measure distance? (maybe not)
    - Does the starting point for GPS calculations match the actual starting point for the movement?
    - What amount of error is inherent in timing gates? (there is some for determining time)
    - These problems were eliminated to some degree by using a VICON system (positional error of only 0.0008%)

Local Positioning Systems (LPS)

- Doesn't require GPS
- Uses "nodes" placed around the training facility to locate a player
- Eliminates one problem but creates others when used in smaller spaces where signal may "bounce" off a wall prior to locating athlete

BRIEF REVIEW

THE VALIDITY AND RELIABILITY OF GLOBAL POSITIONING SYSTEMS IN TEAM SPORT: A BRIEF REVIEW

MACHALAINE T.U. SCOTT,[1,2] TANYAH J. SCOTT,[2,3] AND VINCENT G. KELLY[1,2]

[1]The School of Human Movement and Nutrition Sciences, University of Queensland, Brisbane, Australia; [2]Performance Science Department, Brisbane Broncos Rugby League Club, Brisbane, Australia; and [3]Applied Sport Science and Exercise Testing Laboratory, Faculty of Science and Information Technology, University of Newcastle, Ourimbah, Australia

ABSTRACT

Scott, MTU, Scott, TJ, and Kelly, VG. The validity and reliability of global positioning systems in team sport: a brief review. J Strength Cond Res 30(8): 1470–1490, 2016—The use of global positioning systems (GPS) has increased dramatically over the last decade. Using signals from orbiting satellites, the GPS receiver calculates the exact position of the device and the speed at which the device is moving. Within team sports GPS devices are used to quantify the external load experienced by an athlete, allowing coaches to better manage training loads and potentially identify athletes who are overreaching or over-training. This review aims to collate all studies that have tested either (a) both the validity or reliability of GPS devices in a team sport setting, with a particular focus on (a) measurements of distance, speed, velocities, and accelerations across all sampling rates and (b) accelerometers, playerload, and impacts in accelerometer-integrated GPS devices. A comprehensive search of the online libraries identified 22 articles that fit search criteria. The literature suggests that all GPS units, regardless of sampling rate, are capable of tracking athlete's distance during team sport movements with adequate intra-unit reliability. One Hertz and 5Hz GPS units have limitations in their reporting of distance during high intensity running, velocity measures, and short linear running (particularly those involving changes of direction), although these limitations seem to be overcome during measures recorded during team sport movements. Ten Hertz GPS devices seem the most valid and reliable to date across linear and team sport simulated running, overcoming many limitations of earlier models, whereas the increase to 15Hz GPS devices have had no additional benefit.

KEY WORDS accuracy, consistency, GPS, accelerometer, distance, acceleration, velocity

Address correspondence to Machalaine T. U. Scott, machalaine.t.scott@gmail.com.

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INTRODUCTION

The global positioning system (GPS) is a satellite-based system originally developed by the American Department of Defense for military use, but has since been released to the public and commercialized. It consists of 27 satellites equipped with atomic clocks to orbit around the earth. These satellites continually send information to GPS receivers and, using these signals, the receivers calculate the distance to the satellite (25). This is achieved by comparing the difference in time between the satellite's atomic clock recorded in the signal to the internal clock of the receiver. By calculating the distance to at least 4 satellites, accurate information can be generated regarding the GPS receiver's latitude, longitude, and altitude (25). Commercial GPS receivers, such as those used in team sports, also calculate speed using Doppler shift. This is attained by examining the frequency of the satellite signal, which is subject to change because of the movement of the receiver (28).

However, GPS have been known to have both technological and practical limitations. Satellite signals can be obstructed by the atmosphere and local environmental objects (e.g., stadiums and tall buildings) which can lead to measurement error (28). Likewise, the number of satellites interacting with the GPS receiver seems to play an important role in determining the accuracy of position estimates (29). Although 4 satellites are the theoretical minimum number required to triangulate a GPS receiver's position, there is a moderate negative correlation between the total distance error (i.e., the difference between the recorded distance and the actual distance) recorded by a GPS receiver and the number of satellites signaling the receiver (16). Similarly, velocity measurements can be susceptible to a similar increase in error as the number of satellites interacting with the receiver increases (28). Furthermore, the positioning of satellites interacting with the receiver is also vital in determining the accuracy of measurements recorded by the receiver (28). Quantification of the satellite distribution across the horizon is presented as the measurement known as the dilution of precision (DOP). This measurement is inversely proportion to the volume of a cone delineated by the position of the satellites in relation to the receiver (28).

Accuracy is improved with sampling rate…

- **Distance is improved from 1Hz to 5Hz and even more for 10Hz**
  - SEE for actual distance was as great as 32.4% for 1Hz for 10m sprint (high velocity running)
  - 5Hz was marginally better at 30.9%
  - 10Hz was around 10.9% for a 15m sprint
- **Velocity of a task (not surprisingly) affects the distance accuracy as well**
  - SEE of 0.4 ± 0.1 m/s to 3.8 ± 1.4 m/s between walking and striding with 5hz
  - Low validity for high speed tasks or change of direction tasks
  - Accuracy is improved as distance is increased
    - As low as 1.5% SEE
- **Modern GPS devices use 10Hz sampling rates with 100Hz triaxial accelerometers**
  - No improvement using 15Hz unless you are downhill skiing

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Reliability mimics accuracy…

- Also affected by sampling rate, velocity, duration of the task, and the type of task being performed
- Sprinting with 10Hz GPS over a distance of 15-30m has a coefficient of variation (CV) of 0.7-1.3%
- Once again, the higher the velocity, the lower the reliability
  - Sprinting has lower reliability compared to walking
- Changes of direction reduce reliability, as well as, repetitive tasks in small court areas

PLOS ONE | RESEARCH ARTICLE

Validity and reliability of GPS and LPS for measuring distances covered and sprint mechanical properties in team sports

Matthias W. Hoppe*, Christian Baumgart, Ted Polglaze, Jürgen Freiwald
1 University of Wuppertal, Department of Movement and Training Science, Wuppertal, Germany, 2 University of Western Australia, Exercise and Sport Science, School of Human Sciences, Perth, Australia
* m.hoppe@uni-wuppertal.de

Abstract

This study aimed to investigate the validity and reliability of global (GPS) and local (LPS) positioning systems for measuring distances covered and sprint mechanical properties in team sports. Here, we evaluated two recently released 18 Hz GPS and 20 Hz LPS technologies together with one established 10 Hz GPS technology. Six male athletes (age: 27±2 years; VO2max: 48.8±7.7 ml/min/kg) performed outdoors on 10 trials of a team sport specific circuit that was equipped with double-light timing gates. The circuit included various walking, jogging, and sprinting sections that were performed either in straight lines or with changes of direction. During the circuit, athletes wore two devices of each positioning system. From the reported and filtered velocity data, the distances covered and sprint mechanical properties (i.e., the theoretical maximal horizontal velocity, force, and power output) were computed. The sprint mechanical properties were modeled via an inverse dynamic approach applied to the center of mass. The validity was determined by comparing the measured and criterion data via the typical error of estimate (TEE), whereas the reliability was examined by comparing the two devices of each technology (i.e., the between-device reliability) via the coefficient of variation (CV). Outliers due to measurement errors were statistically identified and excluded from validity and reliability analyses. The 18 Hz GPS showed better validity and reliability for determining the distances covered (TEE: 1.6–9.0%; CV: 1.1–5.1%) and sprint mechanical properties (TEE: 6.0–14.2%; CV: 3.1–7.5%) than the 10 Hz GPS (TEE: 3.9–12.9%; CV: 2.5–13.0%) and TEE: 4.1–23.1%; CV: 3.3–20.1%). Horizontal force was the most sensitive sprint mechanical property (TEE: 10.0–14.2%; CV: 5.7–7.5%) and TEE: 2.1–8.2%; CV: 1.8–7.3%). For the 10 Hz GPS, 18 Hz GPS, and 20 Hz LPS, the relative loss of data sets due to measurement errors was 10.3%, 20.0%, and 15.8%, respectively. This study shows that 18 Hz GPS has enhanced validity and reliability for determining movement patterns in team sports compared to 10 Hz GPS, whereas 20 Hz LPS had superior validity and reliability overall. However, compared to 10 Hz GPS, 18 Hz GPS and 20 Hz LPS technologies had more outliers due to measurement errors, which limits their practical applications at this time.

OPEN ACCESS
Citation: Hoppe MW, Baumgart C, Polglaze T, Freiwald J (2018) Validity and reliability of GPS and LPS for measuring distances covered and sprint mechanical properties in team sports. PLoS ONE 13(2): e0192708. https://doi.org/10.1371/journal.pone.0192708
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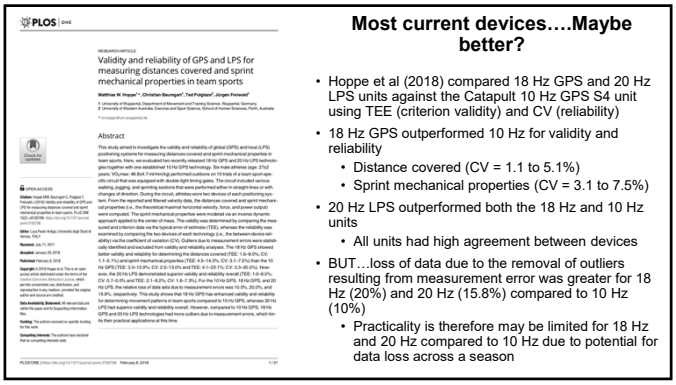

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Most current devices….Maybe better?

- Hoppe et al (2018) compared 18 Hz GPS and 20 Hz LPS units against the Catapult 10 Hz GPS S4 unit using TEE (criterion validity) and CV (reliability)
- 18 Hz GPS outperformed 10 Hz for validity and reliability
  - Distance covered (CV = 1.1 to 5.1%)
  - Sprint mechanical properties (CV = 3.1 to 7.5%)
- 20 Hz LPS outperformed both the 18 Hz and 10 Hz units
  - All units had high agreement between devices
- BUT…loss of data due to the removal of outliers resulting from measurement error was greater for 18 Hz (20%) and 20 Hz (15.8%) compared to 10 Hz (10%)
  - Practicality is therefore may be limited for 18 Hz and 20 Hz compared to 10 Hz due to potential for data loss across a season

VALIDITY AND RELIABILITY OF 15 HZ GLOBAL POSITIONING SYSTEM UNITS FOR ASSESSING THE ACTIVITY PROFILES OF UNIVERSITY FOOTBALL PLAYERS

MATTHEW BARR,[1] TIM BEAVER,[2] DAVID TURCZYN,[2] AND STEPHEN CORNISH[2]
[1]Toronto Argonauts Football Club, Toronto, Ontario, Canada; and [2]Faculty of Kinesiology and Recreation Management, University of Manitoba, Winnipeg, Manitoba, Canada

ABSTRACT

Barr, M, Beaver, T, Turczyn, D, and Cornish, S. Validity and reliability of 15 Hz global positioning system units for assessing the activity profiles of university football players. J Strength Cond Res 33(5): 1371–1379, 2019—Global positioning system (GPS) units have recently become popular for monitoring and assessing the workloads of football players. Currently, there is a lack of studies examining the validity and reliability of these systems for that purpose, as the aim of the current study was to determine whether 15 Hz units (SPI HPU; GPSports, Canberra, Australia) could accurately be used to describe the physical demands of football. A series of cohort studies were conducted with Canadian university football players (n = 36). To assess the accuracy of the units' ability to measure high-velocity sprinting, 13 players performed multiple electronically timed 36.6-m sprints while wearing the units. To assess the intercunit reliability, 8 players wore 3 units each during a training session. An analysis of the units' validity for measuring total and high-intensity (>5.5 m·s−1) distance, and number of tackles and blocks notated on video by an expert rater in 2 games with the number of collisions recorded by the units. The units were accurate for measuring high-sprinting velocities (coefficient of variation [CV] = 0.9%) and had good intercunit reliability for recording distances at velocities between walking and sprinting CV (1.4–7.8%). The collision algorithm filter the accompanying software uses was found to have its best balance between precision and recall using a cut-off of 2.65g for linemen and 2.9g for nonlinemen. The devices used are effective at providing acceptably valid and reliable information to describe the physical demands of football. Position-specific locomotor zones are recommended when using GPS units with football players.

KEY WORDS GPS, Canadian football, training load, collisions

Address correspondence to Matthew Barr, matthew92@hotmail.com.
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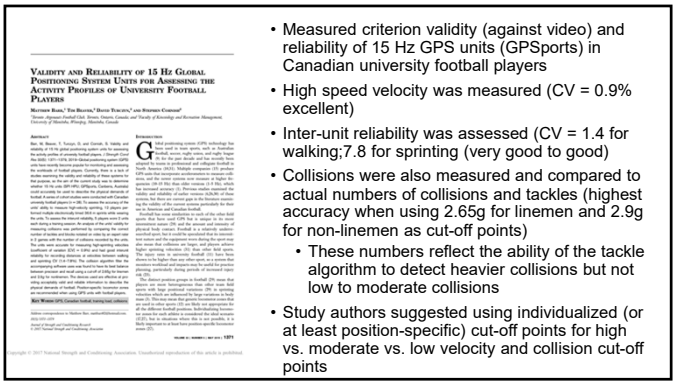
INTRODUCTION

Global positioning system (GPS) technology has been used in team sports, such as Australian football, soccer, rugby union, and rugby league (7) for the past decade and has recently been adopted by teams in professional and collegiate football in North America (16,31). Multiple companies (19) produce GPS units that incorporate accelerometers to measure collisions (9,10) that have been used in the National Football League (10–12) that have older versions (1–5 Hz), which have increased accuracy (1). Previous studies examined the validity and reliability of earlier versions (4,26,30) of these systems, but there are current gaps in the literature examining the validity of the current systems particularly for their use in American and Canadian football.

Football has some similarities to each of the other field sports that have used GPS but is unique in its more intermittent nature (28) and the amount and intensity of physical body contact. Football is a relatively underresearched sport, but it could be speculated that its intermittent nature and the equipment worn during the sport may also mean that collisions are larger, and players achieve higher sprinting velocities (31) than other field sports. The injury rates in university football (11) have been shown to be higher than any other sport, so a system that monitors workload and impacts may be useful for practice planning, particularly during periods of increased injury risk (28).

The distinct position groups in football (29) mean that players are more heterogeneous than other team field sports with large positional variations (29) in sprinting velocities which are influenced by large variations in body mass (2). This may mean that generic locomotor zones that are used in other sports (12) are likely not appropriate for all the different football positions. Individualizing locomotor zones for each athlete is considered the ideal scenario (22,23), but in situations where this is not possible, it is likely important to at least have position-specific locomotor zones (22).



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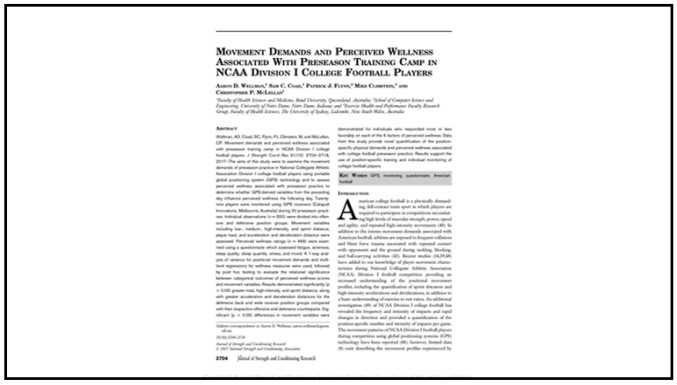
- Measured criterion validity (against video) and reliability of 15 Hz GPS units (GPSports) in Canadian university football players
- High speed velocity was measured (CV = 0.9% excellent)
- Inter-unit reliability was assessed (CV = 1.4 for walking;7.8 for sprinting (very good to good)
- Collisions were also measured and compared to actual numbers of collisions and tackles (highest accuracy when using 2.65g for linemen and 2.9g for non-linemen as cut-off points)
  - These numbers reflect the ability of the tackle algorithm to detect heavier collisions but not low to moderate collisions
- Study authors suggested using individualized (or at least position-specific) cut-off points for high vs. moderate vs. low velocity and collision cut-off points



MOVEMENT DEMANDS AND PERCEIVED WELLNESS ASSOCIATED WITH PRESEASON TRAINING CAMP IN NCAA DIVISION I COLLEGE FOOTBALL PLAYERS

AARON D. WELLMAN,[1] SEAN C. COAN,[1] PATRICK J. FLYNN,[2] MIKE CLEMENTS,[3] AND CHRISTOPHER P. MCLELLAN[1]
[1]Faculty of Health Sciences and Medicine, Bond University, Queensland, Australia; [2]School of Computer Science and Engineering, University of Notre Dame; Notre Dame, Indiana; and [3]Exercise Health and Performance Faculty Research Group, Faculty of Health Sciences, The University of Sydney, Lidcombe, New South Wales, Australia

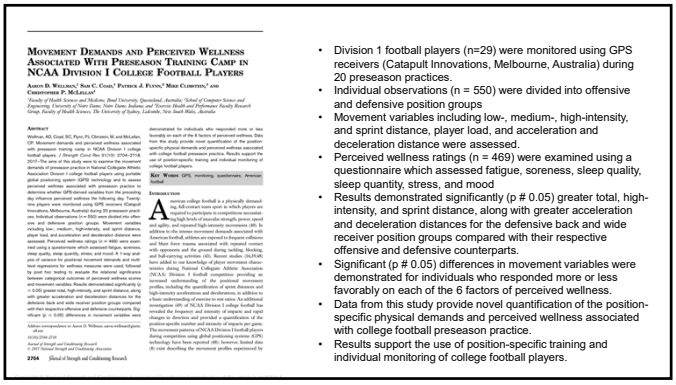
ABSTRACT

Wellman, AD, Coan, SC, Flynn, PJ, Clements, M, and McLellan, CP. Movement demands and perceived wellness associated with preseason training camp in NCAA Division I college football players. J Strength Cond Res 33(5): 1380–1388, 2019—The aims of this study were to examine the movement demands of preseason practice in National Collegiate Athletic Association Division I college football players using portable global positioning system (GPS) technology and to assess perceived wellness associated with preseason practice to determine whether GPS-derived variables from the preceding day influence perceived wellness the following day. Twenty nine players were monitored using GPS receivers (Catapult Innovations, Melbourne, Australia) during 20 preseason practices. Individual observations (n = 550) were divided into offensive and defensive position groups. Movement variables including low-, medium-, high-intensity, and sprint distance, player load, and acceleration and deceleration distance were assessed. Perceived wellness ratings (n = 469) were examined using a questionnaire which assessed fatigue, soreness, sleep quality, sleep quantity, stress, and mood. Results demonstrated significantly ($p \# 0.05$) greater total, high-intensity, and sprint distance, along with greater acceleration and deceleration distances for the defensive back and wide receiver position groups compared with their respective offensive and defensive counterparts. Significant ($p \# 0.05$) differences in movement variables were demonstrated for individuals who responded more or less favorably on each of the 6 factors of perceived wellness. Data from this study provide novel quantification of the position-specific physical demands and perceived wellness associated with college football preseason practice. Results support the use of position-specific training and individual monitoring of college football players.

KEY WORDS GPS, monitoring, questionnaire, American football

INTRODUCTION

American college football is a physically demanding, full-contact team sport in which players are required to participate in competitions necessitating high levels of muscular strength, power, speed and agility (28). Competition requirements (28) in addition to the intense movement demands associated with American football, athletes are exposed to frequent collisions and Short force trauma associated with repeated contact with opponents and the ground during tackling, blocking, and ball-carrying activities (16). Recent studies (16,19,28) have added to our knowledge of player movement characteristics during National Collegiate Athletic Association (NCAA) Division I football competition providing an overall quantification of the physical demand profiles, including the quantification of sprint distances and high-intensity accelerations and decelerations, in addition to a basic understanding of exercise to rest ratios. An additional investigation (19) of NCAA Division I college football has revealed the frequency and intensity of impacts and rapid changes in direction and provided a quantification of the physical demands and perceived wellness associated with preseason training camp. Data from a single team of NCAA Division I football players during competition using global positioning systems (GPS) technology have been reported (16); however, limited data (8) exist describing the movement profiles experienced by



MOVEMENT DEMANDS AND PERCEIVED WELLNESS ASSOCIATED WITH PRESEASON TRAINING CAMP IN NCAA DIVISION I COLLEGE FOOTBALL PLAYERS

AARON D. WELLMAN,[1] SEAN C. COAN,[1] PATRICK J. FLYNN,[2] MIKE CLEMENTS,[3] AND CHRISTOPHER P. MCLELLAN[1]
[1]Faculty of Health Sciences and Medicine, Bond University, Queensland, Australia; [2]School of Computer Science and Engineering, University of Notre Dame; Notre Dame, Indiana; and [3]Exercise Health and Performance Faculty Research Group, Faculty of Health Sciences, The University of Sydney, Lidcombe, New South Wales, Australia

ABSTRACT

Wellman, AD, Coan, SC, Flynn, PJ, Clements, M, and McLellan, CP. Movement demands and perceived wellness associated with preseason training camp in NCAA Division I college football players. J Strength Cond Res 33(5): 1380–1388, 2019—The aims of this study were to examine the movement demands of preseason practice in National Collegiate Athletic Association Division I college football players using portable global positioning system (GPS) technology and to assess perceived wellness associated with preseason practice to determine whether GPS-derived variables from the preceding day influence perceived wellness the following day. Twenty nine players were monitored using GPS receivers (Catapult Innovations, Melbourne, Australia) during 20 preseason practices. Individual observations (n = 550) were divided into offensive and defensive position groups. Movement variables including low-, medium-, high-intensity, and sprint distance, player load, and acceleration and deceleration distance were assessed. Perceived wellness ratings (n = 469) were examined using a questionnaire which assessed fatigue, soreness, sleep quality, sleep quantity, stress, and mood. Results demonstrated significantly ($p \# 0.05$) greater total, high-intensity, and sprint distance, along with greater acceleration and deceleration distances for the defensive back and wide receiver position groups compared with their respective offensive and defensive counterparts. Significant ($p \# 0.05$) differences in movement variables were demonstrated for individuals who responded more or less favorably on each of the 6 factors of perceived wellness. Data from this study provide novel quantification of the position-specific physical demands and perceived wellness associated with college football preseason practice. Results support the use of position-specific training and individual monitoring of college football players.

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INTRODUCTION

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- Division 1 football players (n=29) were monitored using GPS receivers (Catapult Innovations, Melbourne, Australia) during 20 preseason practices.
- Individual observations (n = 550) were divided into offensive and defensive position groups
- Movement variables including low-, medium-, high-intensity, and sprint distance, player load, and acceleration and deceleration distance were assessed.
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- Significant ($p \# 0.05$) differences in movement variables were demonstrated for individuals who responded more or less favorably on each of the 6 factors of perceived wellness.
- Data from this study provide novel quantification of the position-specific physical demands and perceived wellness associated with college football preseason practice.
- Results support the use of position-specific training and individual monitoring of college football players.

NONINVASIVE ASSESSMENT OF INTERNAL AND EXTERNAL PLAYER LOAD: IMPLICATIONS FOR OPTIMIZING ATHLETIC PERFORMANCE

AARON D. HUGHES,[1#] MICHAEL A. CURTIS,[2#] EVRAN SACHA,[1,2] ROBERT J. HOOVER,[3] STEVEN R. MALIN,[2] AND ARTHUR L. WELTMAN[1,2]

Departments of Kinesiology, [1]Athletics, Basketball Strength and Conditioning, and [2]Athletics, Sports Medicine, University of Virginia, Charlottesville, Virginia, and [3]Division of Endocrinology and Metabolism, University of Virginia, Charlottesville, Virginia

ABSTRACT

Hughes, AD, Curtis, MA, Sacha, E, Hoover, RJ, Malin, SK, and Weltman, AL. Noninvasive assessment of internal and external player load: implications for optimizing athletic performance. *J Strength Cond Res* 00(0): 1080–1087, 2019—Prior to the commencement of a competitive season, it is critical to the development of strategies to optimize performance and reduce fatigue in elite athletes. The purpose of the present study was to assess the efficacy of external load and internal stress monitoring as assessment tools for examining a performance index of fatigue. A retrospective analysis was performed on data collected over the course of the preseason in 10 elite male NCAA Division 1 basketball players. Internal stress was assessed using Omegawave Technology readiness scores and compared to the performance index of countermovement jump (CMJ). The external load that accumulated during the previous practice, specified by PlayerLoad (PL; Catapult), was compared with CMJ values and Omegawave scores. The results indicated that high, compared to low CNS Omegawave Readiness (Scores 8.7 ± 19.1, 60.4 ± 5.2 AU, $p < 0.001$), were associated with increased CMJ (58.7 ± 4.9 cm vs. 60.4 ± 5.1 cm; p , 0.001) and increased TRIMP (135.1 ± 35.9 vs. 65.6 ± 20.0 AU; p , 0.001), and Omega Potential (Omega) (25.0 ± 9.0 vs. 9.0 ± 27.8 ms), $p = 0.05$. An increased PL during the previous exposure was associated with decreased CMJ (58.7 ± 4.7 cm vs. 60.4 ± 5.1 cm, $p < 0.001$) and increased TRIMP (135.1 ± 35.9 vs. 65.6 ± 20.0 AU; $p < 0.001$), and duration (115.4 ± 27.1 vs. 65.56 ± 20.0 minutes; p = , 0.001) despite no differences in Omega-wave CNS Readiness scores. We conclude that Omegawave and Catapult technologies provide independent information related to performance and may be effective tools for monitoring athlete performance.

Address correspondence to Dr. Arthur L. Weltman, dw5ehw@virginia.edu.

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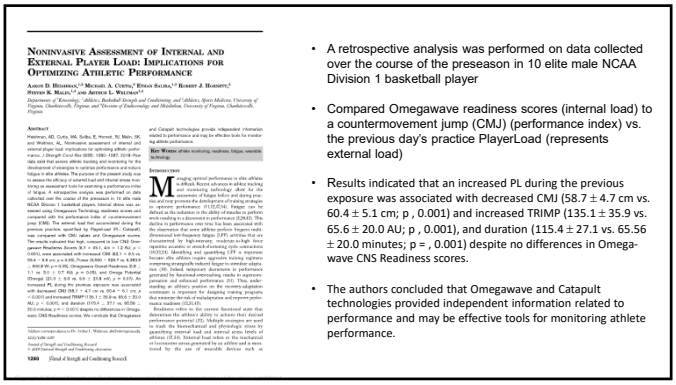


NONINVASIVE ASSESSMENT OF INTERNAL AND EXTERNAL PLAYER LOAD: IMPLICATIONS FOR OPTIMIZING ATHLETIC PERFORMANCE

- A retrospective analysis was performed on data collected over the course of the preseason in 10 elite male NCAA Division 1 basketball player
- Compared Omegawave readiness scores (internal load) to a countermovement jump (CMJ) (performance index) vs. the previous day's practice PlayerLoad (represents external load)
- Results indicated that an increased PL during the previous exposure was associated with decreased CMJ (58.7 ± 4.7 cm vs. 60.4 ± 5.1 cm; p , 0.001) and increased TRIMP (135.1 ± 35.9 vs. 65.6 ± 20.0 AU; p , 0.001), and duration (115.4 ± 27.1 vs. 65.56 ± 20.0 minutes; p = , 0.001) despite no differences in Omega-wave CNS Readiness scores.
- The authors concluded that Omegawave and Catapult technologies provided independent information related to performance and may be effective tools for monitoring athlete performance.

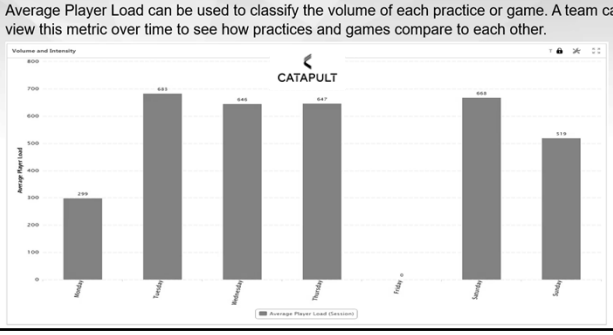
So what does this look like in a field setting?

Catapult metrics of interest…

- Player load – a measure of activity volume
- Player load per minute – a measure of activity intensity
- Total distance – the amount of distance covered in a session
- High speed running – the amount of distance covered at a speed above the high speed threshold (determined by sport, level, position, etc)
- High IMA – the number of high intensity events accrued in any direction (acceleration, deceleration, change of direction left and right)

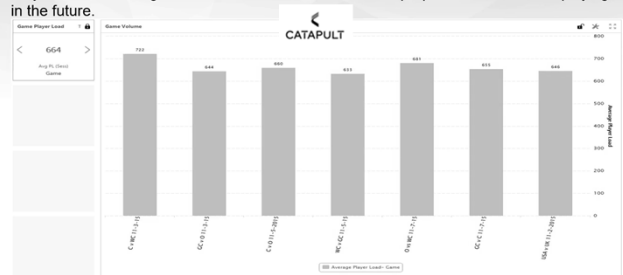
Player Load

- Usage Example 1:
- Average Player Load can be used to classify the volume of each practice or game. A team can view this metric over time to see how practices and games compare to each other.



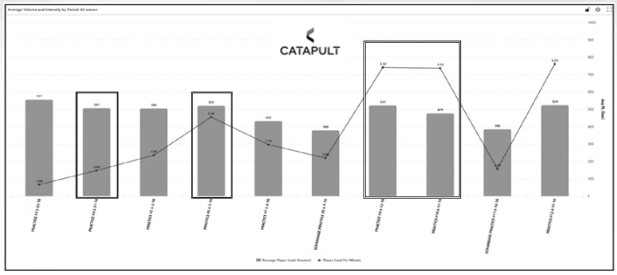
Player Load

- Usage Example 2:
- Coach A wants to see how his games compared to each other. This graph shows the average Player Load of each game. He can use this information to prepare for each teams playing style in the future.



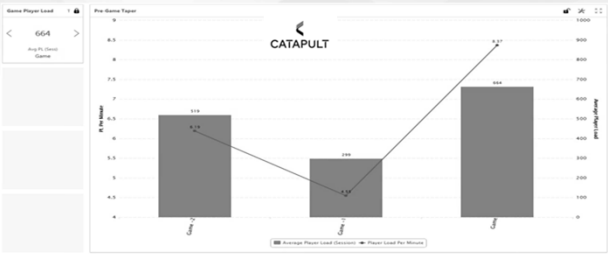
Player Load per Minute

- Usage Example 1:
- Player Load and Player Load per Minute can be shown on the same graph. This will create a more complete activity profile showing both the volume and intensity of the practice or game.



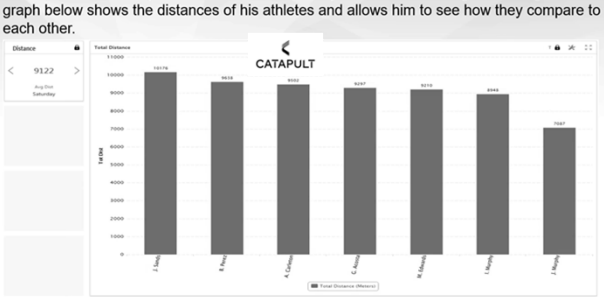
Player Load per Minute

- Usage Example 2:
- Coach A wants to make sure that he is not overworking his players on days leading up to games. The graph below shows the volume and intensity of the two days leading up to games and the games themselves.



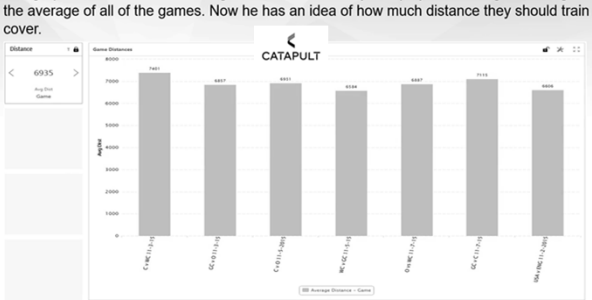
Total Distance

- Usage Example 1:
- Coach A wants to compare the distance covered by his receivers during a certain game. The graph below shows the distances of his athletes and allows him to see how they compare to each other.



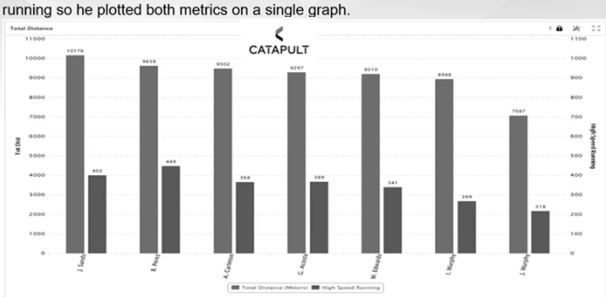
Total Distance

- Usage Example 2:
- The graph below shows the average distance covered by one player in each game along with the average of all of the games. Now he has an idea of how much distance they should train to cover.



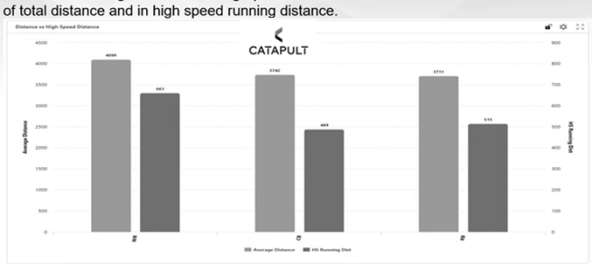
High Speed Distance

- Usage Example 1:
- Coach A wants to see how much of his receivers' total distance consisted of high speed running so he plotted both metrics on a single graph.



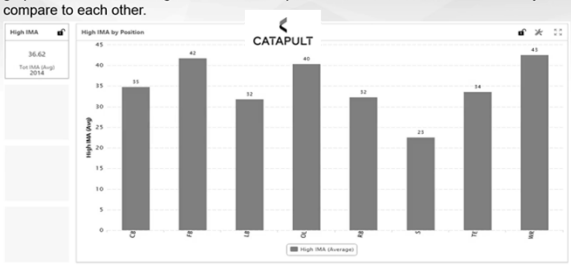
High Speed Distance

- Usage Example 2:
- Coach A wants to compare the running profiles of his receivers, corner backs, and running backs for the last game. The below graph shows him that his receivers ran more both in terms of total distance and in high speed running distance.



Inertial Motion Analysis (IMA)

- Usage Example 1:
- Coach A wants to compare the high intensity events his team is experiencing by position. The graph below shows the High IMA totals of his positions and allows him to see how they compare to each other.



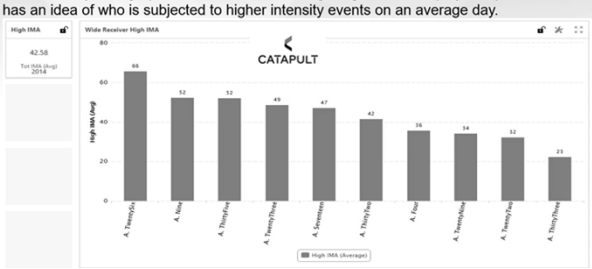
How I normally explain IMA…

Liberty Mutual tells me "high risk" events = $$$, whereas my moderate and low risk events (stops, starts, turns) are not as risky

They use this data to build a risk profile for you as a driver

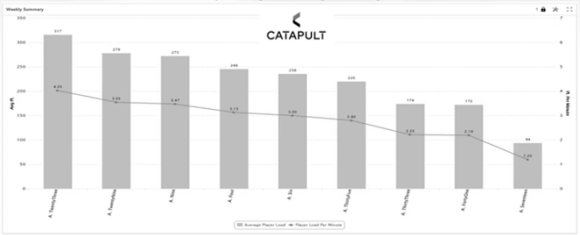
Inertial Motion Analysis (IMA)

- Usage Example 2:
- Based on his findings above, Coach A wants to see which of his receivers are experiencing the most intensity. The graph below shows the average High IMA each player experiences. Now he has an idea of who is subjected to higher intensity events on an average day.



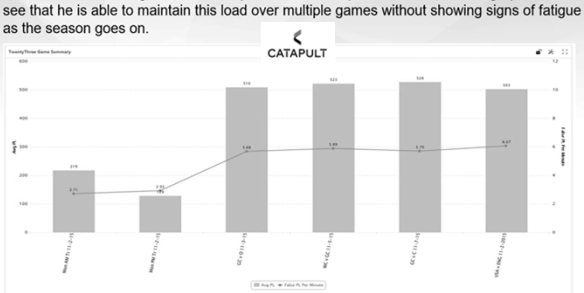
Player Performance

- Player performance can be tracked across any metric. For this example we will be using Player Load (Volume) and Player Load per Minute (intensity).
- The graph below shows average volume and intensity over the past week for each player. We can see that Athlete TwentyThree is much higher in both categories than the rest of the team. We will want to monitor him closely for signs of fatigue and give him a rest if need be.



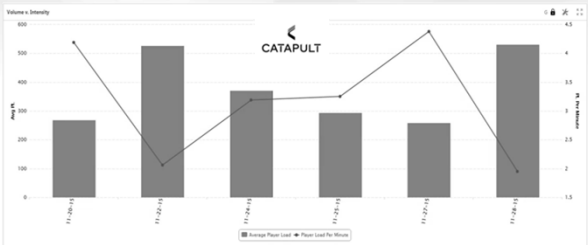
Player Performance

- We can break these numbers down even further and look at Athlete TwentyThree's volume and intensities over a few games with two practices for comparison. On the below graph we can see that he is able to maintain this load over multiple games without showing signs of fatigue as the season goes on.



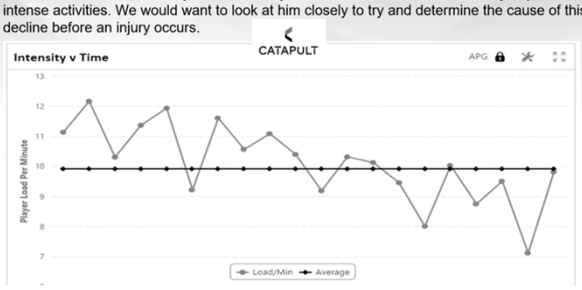
Periodization

- Player Load and Player Load per minute are good summary numbers that give you an idea of how hard the game or practice was. These numbers can help you create and visualize your practice workloads in order to develop a periodization plan. Generally you want a harder practice earlier in the week, and taper the load as you approach a game.



Injury Risk

- The graph below shows a players intensity output against his average over a period of 20 days. His total volume on these days is similar so you can see the decline in his ability to perform intense activities. We would want to look at him closely to try and determine the cause of this decline before an injury occurs.



So what skills do you need to do this work?

- A knowledge of the technical/biomechanical, tactical, and physiological demands of the sport
- An integrative knowledge of how coaches think, along with the needs/concerns/interests of the rest of the support staff (S&C, nutrition, psych, medicine) within an athletic environment
- Outstanding organizational ability in excel (pivot tables, macros, graphing)
  - There are other programs but this is where everyone starts
- A team
  - You can not use this technology to its intent or potential collecting a few weeks data with a few people
  - This technology was designed for real time awareness of an athlete's acute status and long-term, deep-dive analysis to better understand performance opportunities and injury alerts/risk

Thank you to everyone…. But especially

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- My Wife, Tiffany
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- jcampbell21@ou.edu
- (205) 435-1935
- @drjayacampbell
- @DrJayCampbell