
BSMPG
The Boston Sports Medicine and Performance Group
ELITE ATHLETE MONITORING SYSTEMS
METHODS & TECHNIQUES FOR ASSESSING RECOVERY IN ATHLETES
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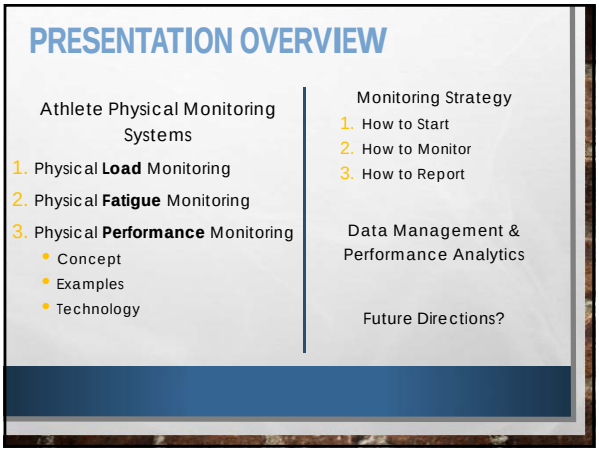
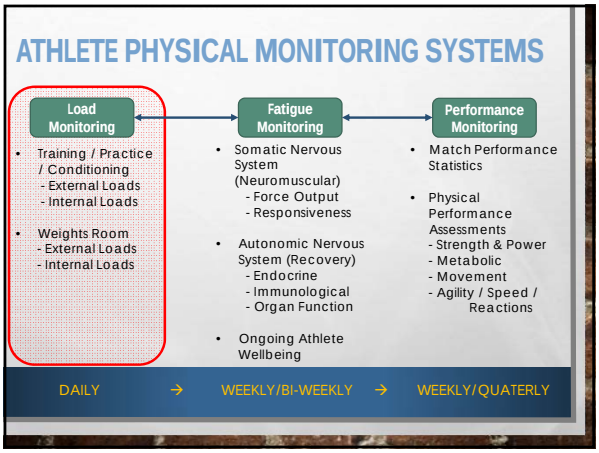

PRESENTATION OVERVIEW
Athlete Physical Monitoring Systems
1. Physical Load Monitoring
2. Physical Fatigue Monitoring
3. Physical Performance Monitoring
• Concept
• Examples
• Technology
Monitoring Strategy
1. How to Start
2. How to Monitor
3. How to Report
Data Management & Performance Analytics
Future Directions?


ATHLETE PHYSICAL MONITORING SYSTEMS
Load Monitoring
• Training / Practice / Conditioning
- External Loads
- Internal Loads
• Weights Room
- External Loads
- Internal Loads
Fatigue Monitoring
• Somatic Nervous System (Neuromuscular)
- Force Output
- Responsiveness
• Autonomic Nervous System (Recovery)
- Endocrine
- Immunological
- Organ Function
• Ongoing Athlete Wellbeing
Performance Monitoring
• Match Performance Statistics
• Physical Performance Assessments
- Strength & Power
- Metabolic
- Movement
- Agility / Speed / Reactions
DAILY → WEEKLY/BI-WEEKLY → WEEKLY/QUATERLY

LOAD MONITORING
Concept

- Load monitoring = Quantification and tracking of physiological (internal) and biomechanical (external) demands relating to exercise.
  - *How much are the athletes doing?*
  - *How does this change over time?*
- Provides feedback on **PLANNED VS ACTUAL EXERCISE.**
- Load monitoring can be broken into –
  - **External load** (biomechanical) – Volume, intensity & density of movements
  - **Internal load** (physiological) - Physiological response of the body to demands of movement

Exercise Load = Volume, Intensity & Density

LOAD MONITORING
Research

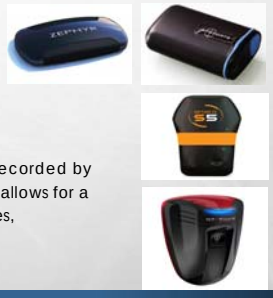
- What does the research say?
  - There is no **single** definitive measure to measure loads (Halson 2014)
  - Use a **combination** of internal & external load monitors (Weaving 2014)
- *Performance*
  - Increased knowledge of sport specific training & match demands.
    - Significant differences in external demands of playing positions (McLellan, 2008 & 2014)
    - Significant differences in internal demands of playing positions (Kempton 2015)
- *Injuries*
  - Higher rates of injury occur when training load is not correctly balanced.
    - Increase in the 3-week external load. Increase risk of injury - AFL (Colby, 2014)
    - Spikes in week-to-week external load. Increase risk of injury – Cricket (Hulin, 2013)

LOAD MONITORING
EXTERNAL LOAD

- What metrics exist to measure?
  - Movement characteristics of training & conditioning
  - Force characteristics of movement
    - Total volume
    - Ratios of high intensity to low intensity
    - Density of movements at specific time periods
  - Power output, velocities, forces and distances of weights room movements
    - How these progress with training?
    - How these change with fatigue?

EXTERNAL LOAD MONITORS

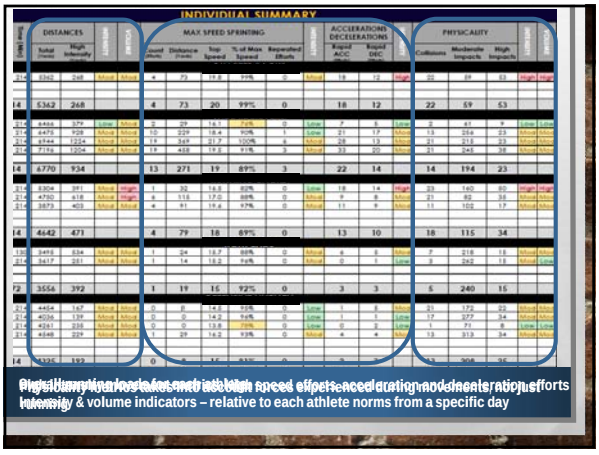
GPS/ INTEGRATED ACCELEROMETER / CAMERA SYSTEMS



- Outdoor & indoor movement quantification solutions.
  - External loads
- Total change in player position recorded by these monitoring platforms then allows for a calculation of distance, velocities, accelerations, forces.

Start by quantifying COMPETITION demands

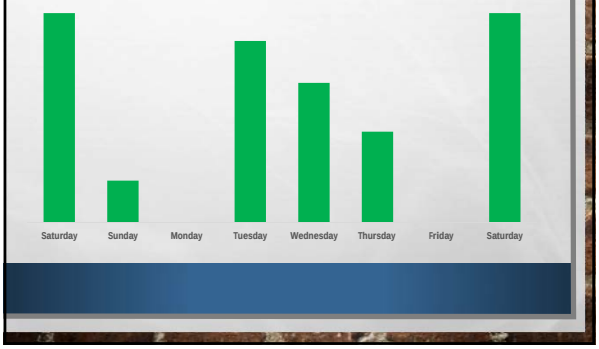
Running Zone Distances For Different Football Positions					
Total Distance	5530.6 ± 996.5	3140.6 ± 685.6	3751.9 ± 801.9	3574.2 ± 882.2	3652.4 ± 603.0
Low Intensity Distance	4642.6 ± 373.3	2270.9 ± 239.6	3570.3 ± 313.2	3224.6 ± 299.7	3397.3 ± 242.5
High Intensity Distance	887.9 ± 116.6	369.7 ± 62.0	181.6 ± 35.6	344.7 ± 62.0	125.8 ± 24.3
HI TO LI Ratio	1: 5	1 : 6	1 : 20	1 : 10	1 : 33
Forces Profile For Different Football Positions					
Moderate Impacts	211.1 ± 35.7	99.8 ± 20.9	57.3 ± 9.1	206.8 ± 36.4	193.1 ± 62.4
Heavy Impacts	23.4 ± 5.3	26.1 ± 6.4	22.3 ± 5.6	15.1 ± 3.4	23.9 ± 6.6
HI TO MI (Impacts) Ratio	1 : 10	1 : 4	1 : 2	1 : 15	1 : 8

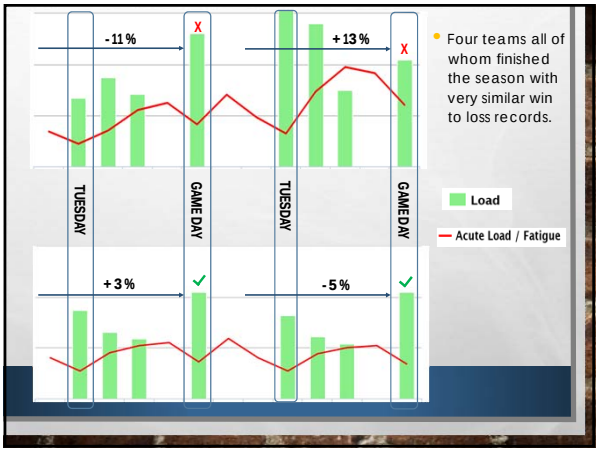


Intensity & volume indicators – relative to each athlete norms from a specific day

LOADING SCHEME EXAMPLE

PLANNED WEEKLY LOADING



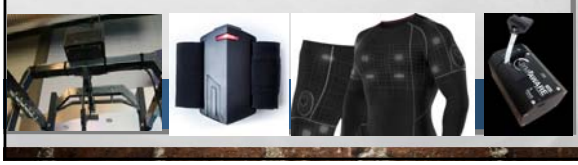


- Four teams all of whom finished the season with very similar win to loss records.

External Load Monitors

Accelerometer / Force Transducers / Sensory Tech

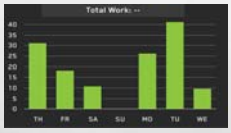
- Movement quantification solutions.
  - Wearable's – Clothes / bands - biofeedback (internal loads)
  - Connectable's – Force transducers
  - Viewable's – Camera systems
- Investigation of **PLANNED VS ACTUAL LOADS.**
- Real-time feedback and adjustments to training based on performance rather than planning.



Finding the ideal training zone in real time

Measures force & velocity of movements

Real-time feedback athlete feedback. **Stored for post analysis**



Technology which automatically records, stores information and generates reports

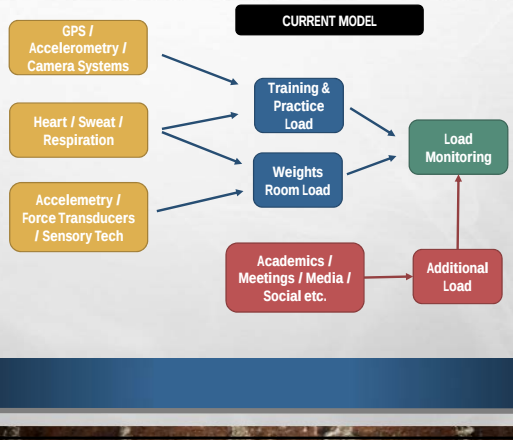
Load Monitoring

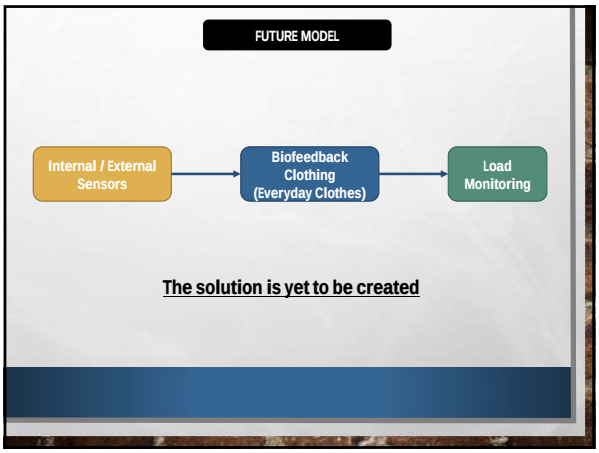
Internal Load – Physiological load

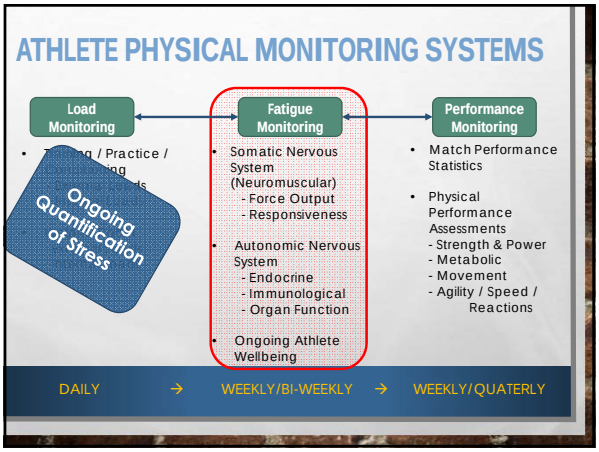
What is the response of physiological function to training & competition?

Measurement include:

- Heart rate monitors
  - How does the cardiovascular system react to training?
- Respiratory rate monitors
  - How does the pulmonary system react to exercise?
- Sweat rate monitoring
  - Changes in internal fluid balance and osmolality.




FUTURE MODEL
Internal / External Sensors
Biofeedback Clothing (Everyday Clothes)
Load Monitoring
The solution is yet to be created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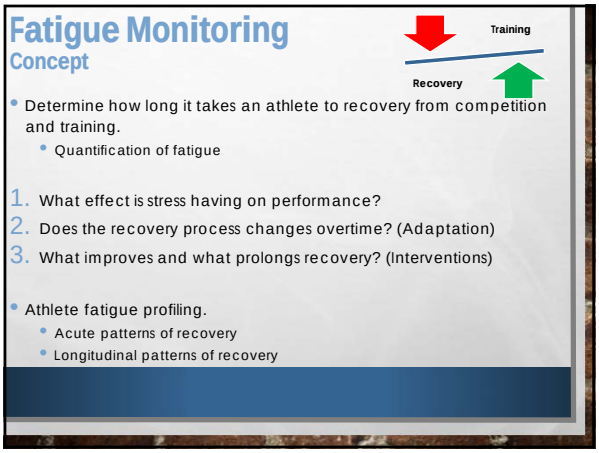
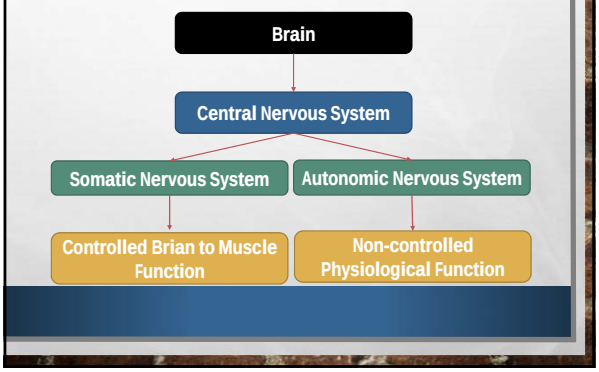
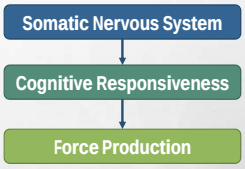

Fatigue Monitoring
Concept
Training
Recovery
Determine how long it takes an athlete to recovery from competition and training.
Quantification of fatigue
1. What effect is stress having on performance?
2. Does the recovery process changes overtime? (Adaptation)
3. What improves and what prolongs recovery? (Interventions)
Athlete fatigue profiling.
Acute patterns of recovery
Longitudinal patterns of recovery

Fatigue Monitoring
Recovery Profiling

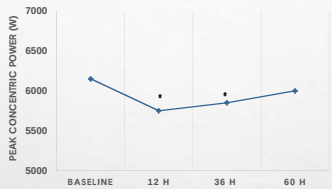


Fatigue Monitoring
Somatic Nervous System

- How does brain to muscle function change due to exercise fatigue?
  - Development of force during contractions?
  - Responsiveness to stimuli?



- **Research Says -**
  - Measurements of neuromuscular force can be directly effected by exercise loads (Wehbe 2014).
  - Decrements in neuromuscular performance can lead to under performance and heighten risk of injury (Mooney 2013, Wilkerson 2015).



????

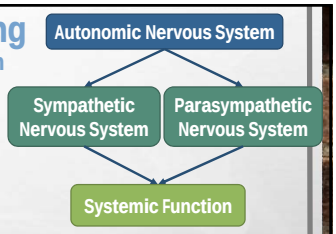
- Rugby union post-match time course power production profile (West 2013).
- May take up to 60 hours post-match to fully recover max concentric power.
- How does neuromuscular responsiveness change in the hours after match-play?

Somatic Nervous System
Technology & Tests

- Force development assessments (muscle output)
  - Force platforms
  - Isokinetic/Isometric testing - machines
  - Ergometer testing – treadmills, bikes, rowers, etc

- Responsiveness assessment (brain output)
  - Reaction speed & accuracy
  - Stress reaction speed / accuracy
  - Slow responsiveness linked to increased incidences of strains and sprains (Wilkerson 2015).

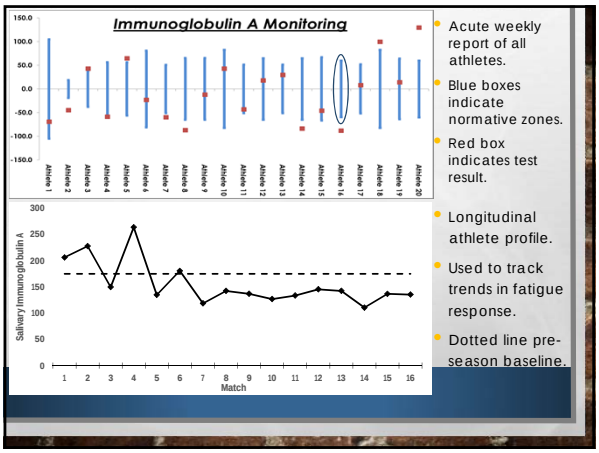
Fatigue Monitoring
Autonomic Nervous System



- How does underlying physiological function alter as a result of stress?
- What effect does stress have on physiological restoration?
- **Research Says -**
  - Links between increased basal sympathetic activity and overreaching / overtraining (Nederhof 2006).
  - Prolonged recovery durations in athletes with altered autonomic balance.

Fatigue Monitoring
Autonomic Nervous System

- **What can you measure?**
- Heart Rate Variability (HRV)
  - Indicator of parasympathetic/sympathetic balance.
- Saliva/Blood
  - Immunological response
  - Neurological response
  - Endocrinological response
  - Hematological response



- Acute weekly report of all athletes.
- Blue boxes indicate normative zones.
- Red box indicates test result.
- Longitudinal athlete profile.
- Used to track trends in fatigue response.
- Dotted line pre-season baseline.

Fatigue Monitoring
Athlete Wellbeing

- Measure which provide information regarding ongoing wellbeing.
  - Include
    - Sleep
    - Hydration / Nutrition
    - Perceptual (how an athlete perceives there current state)
- Key areas which contribute to athlete recovery.
- Athletes need to be elite in these areas to accomplish optimal recovery. As such, monitoring technology can highlight problems in these areas.

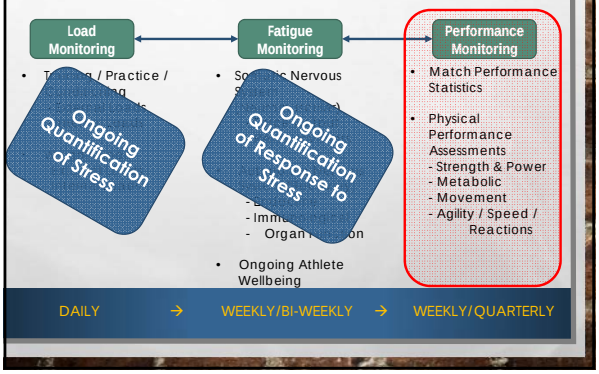
Athlete Wellbeing
Technology

- Sleep
  - **EDUCTATION IS THE KEY**
  - Vitally important to physiological restoration, a key contributor to the recovery process.
  - Easy to implement wrist band, wearable's, or fitted sheet monitoring technology.
- Hydration / Nutrition
  - **EDUCTATION IS THE KEY**
  - Similar to sleep, is a key component on physiological restoration.
  - Weights, USG, sweat patches, real-time wearable's, ultrasound.
- Perceptual
  - **EDUCTATION IS THE KEY**
  - Highly individualized measure, can not compare athlete 1 to athlete 2.
  - Questionnaires very easy to implement can provide basic feedback on mental state.

ATHLETE MONITORING
HOW TO BRING IT ALL TOGETHER?

- Needs to be time efficient! No more than 30 minutes.
  - Fast information turn around. If it takes more than 6 hours to go from collecting to reporting its to slow
- Avoid calling it "fatigue" monitoring. Needs to be a positive engaging environment.
  - **DIFFICULT TO DO!!** Think outside the box on how to make monitoring something that doesn't become strenuous/boring!
- Avoid telling an athlete they are fatigued.
  - Instantly effects their mental state
  - Get the athletes opinion first, then provide feedback
  - Be smart with your feedback.

ATHLETE PHYSICAL MONITORING SYSTEMS



Performance Monitoring
Concept

- **Longitudinal relationship to PERFORMANCE characteristics.**
  - Tactical efficiency, skills outcomes, coaches ratings
  - Sports specific physical performance
  - **Evidence based "Key Performance Indicators"**
- Should be used to determine what effect the program is having on the athletes development / competition performance.
  - Determine strengths, weakness, areas of development
  - Assess how these change over time
  - Assess how changes effect on field performance

PERFORMANCE MONITORING

Form

Round	19	18	17	16	15	14	13	12
Level	AFL	AFL	AFL	AFL	AFL	AFL	AFL	AFL
Offence	85%	100%	64%	76%	94%	83%	75%	71%
Defence	71%	50%	67%	65%	78%	21%	52%	63%
Stoppage	81%	75%	91%	46%	100%	40%	80%	73%

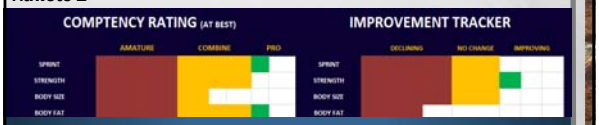
Player Building Blocks Ratings

	Flow of Play	Keyway	Launch Zone	Ball	Deny	Help	Starting Points	Engage/ Sepaate	Drive Legs	Commun ication
Rd 19	3	2	2	2	2	2	2	2	2	3
Rd 18	2	2	2	2	1	2	1	1	1	2
Rd 17	2	1	1	1	1	2	1	1	1	2
Rd 16	1	1	1	2	1	2	2	2	2	1

Physical Performance Examples

Athlete 1

Athlete 2



ATHLETE PHYSICAL MONITORING SYSTEMS

Load Monitoring

- T... / Practice /

Ongoing Quantification of Stress

Fatigue Monitoring

- S... tic Nervous

Ongoing Quantification of Response to Stress

- Imm...
- Organ... tion
- Ongoing Athlete Wellbeing

Performance Monitoring

- M... Performance

Ongoing Quantification of Performance / Development

- M...
- Agility ... React...

DAILY → WEEKLY/BI-WEEKLY → WEEKLY/QUARTERLY

INTEGRATION OF TECHNOLOGY
HOW TO START

1. Define what it is you want to solve.
2. Research the technology - is it valid and reliable?
3. Investigate alternative technologies available.
4. Think of what about the future.
5. Educate those around you. Let them educate you!
6. Plan outcomes based on new information.
7. Avoid making initial wholesale changes.

HOW TO MONITOR

- Quantify normal and abnormal results for your outcome based plan.
  - Don't monitor for monitoring's sake
- Consistency is the key, if you plan to monitor once a week, don't skip weeks (unless the reason is unavoidable).
  - Longitudinal trends often are not apparent right away - *PATIENCE*
- Make sure to provide ***APPROIATE FEEDBACK*** in a timely manner.

HOW TO REPORT

Layer your reports depending on your audience.

- **1st layer** Coaches reports. Non-experts, and need a basic snapshot to aid decision making.
- **2nd layer** Performance group, those who grasp the overall concepts, however may not understand all the data.
- **3rd Layer** Performance experts report, the most detailed level of reporting.

REPORTING LAYERS

Athlete Name	Position	Weekly Performance Score / 100 %	Weekly Load Score / 100 %	Weekly Fatigue Score / 100%
Athlete 1	QB	87	89	90
Athlete 2	QB	0	97	85
Athlete 3	WR	80	105	78
Athlete 4	WR	74	145	68
Athlete 5	WR	95	95	84
Athlete 6	WR	60	62	98
Athlete 7	WR	84	87	92
Athlete 8	WR	31	96	91
Athlete 9	RB	74	98	87
Athlete 10	RB	65	94	86
Athlete 11	RB	84	102	81
Athlete 12	RB	94	101	92
Athlete 13	TE	64	98	91
Athlete 14	TE	75	103	97
Athlete 15	OL	84	78	98
Athlete 16	OL	87	88	78
Athlete 17	OL	86	89	65
Athlete 18	OL	65	41	98
Athlete 19	OL	94	106	87

EXAMPLE REPORT FOR COACHING STAFF

REPORTING LAYERS

Athlete Name	Position	Weekly Load Score / 100	Weekly Fatigue Score / 100	Heart Rate Variability /20	Counter Movement Jump / 20	Mobility / 20	Perceptual / 20	Reaction Times / 20
Athlete 1	QB	89	81	18	14	15	17	17
Athlete 2	QB	97	79	14	15	14	18	18
Athlete 3	WR	105	88	19	17	19	18	15
Athlete 4	WR	145	69	15	14	14	14	16
Athlete 5	WR	95	80	15	14	18	16	17
Athlete 6	WR	62	78	18	17	19	8	19
Athlete 7	WR	87	80	17	16	18	15	14
Athlete 8	WR	96	82	18	17	17	13	19
Athlete 9	RB	98	78	18	18	14	17	13
Athlete 10	RB	94	86	18	19	17	18	14
Athlete 11	RB	102	75	15	13	15	16	15
Athlete 12	RB	101	83	14	18	16	19	20
Athlete 13	TE	98	85	17	18	19	14	17
Athlete 14	TE	103	83	15	17	18	15	18
Athlete 15	OL	78	79	16	14	19	16	16
Athlete 16	OL	88	78	13	16	17	18	15
Athlete 17	OL	89	89	17	19	16	19	18
Athlete 18	OL	41	90	18	18	19	16	20
Athlete 19	OL	106	78	16	12	19	13	20

EXAMPLE REPORT FOR PERFORMANCE STAFF

REPORTING LAYERS

Athlete Information			General Outputs					Eccetric Phase			Development Phase			Concentric Phase			Durations			
Athlete																				

EXAMPLE REPORT FOR PERFORMANCE EXPERTS

ATHLETE DATA SYSTEMS

- **COMMON DATA SCENARIO**

If you collect GPS and Weights Room Loads 3 days a week, and 1 x jump testing and HRV testing on 40 athletes.

You will generate 440 separate datasets per week.

If there is an average of 4 data points per dataset, per athlete.

You will generate 1,760 data points per week.

If the in-season is 12 weeks.

You will generate 21,120 data points per season.

Have fun organizing that in excel…….. And forget about adding more testing!

Solution → Data Analytics Software

DATABASES & DATA ANALYTICS
SOFTWARE

WHAT TO LOOK FOR

- Automatic communication from technology to database software.
  - Otherwise you will spend hours storing data
- Fast and customizable reporting.
  - Otherwise you will spend hours making reports
- High quality relationship with vendor.
  - So that when new technology or methods change, the software system can change with it

DATABASES & DATA ANALYTICS
SOFTWARE

WHAT TO WATCH OUT FOR

- Complicated software.
  - If it takes ten clicks to find information – It's complicated!
- Poor education on software use.
  - Make sure the company is committed to teaching your staff (ongoing)
- Fast sales.
  - Everyone wants a product NOW! Take the time to make sure your not purchasing software which could be useless in 12 months

FUTURE ??

- Biofeedback clothing technology.
  - Smart Clothes!
- Automatic collaboration of data.
  - Smart Data!
  - Injury, fatigue and performance prediction models.
- Genetics
  - Will we train, recovery, prepare athletes based on genotype to achieve the best adaptations?
  - Can we predict injuries based on genetics?

FINAL REMARKS

- All the bells and whistles of technology will not hide a poorly planned performance program. The fundamentals don't change.
- Athlete monitoring provides a new level of feedback to ensure goals are achieved.
- An athlete monitoring program does not aid an inflexible performance program.

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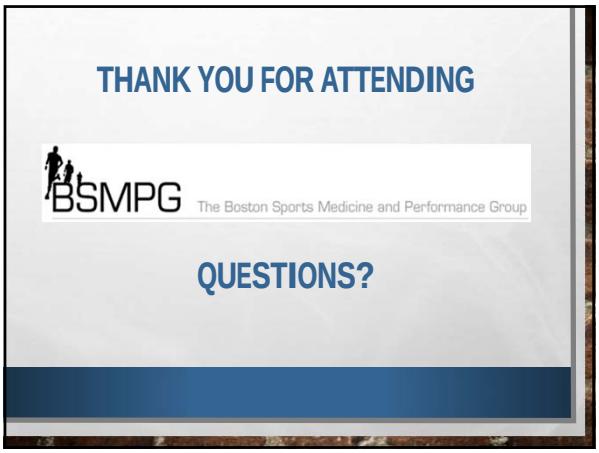
THANK YOU FOR ATTENDING
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QUESTIONS?