University of Verona,

School of Exercise and Sport Science,

Laurea magistrale in Scienze motorie preventive ed adattate

(Laurea magistrale in Scienze dello sport individuali e squadra,

Laurea magistrale in Scienze dello sport e montagna)

Metodologia delle misure delle attività sportive

Thursday 10/10/2019 14÷15:30

Luca P. Ardigò Ph.D.

A class within an ten-class module

University of Verona,

School of Exercise and Sport Science,

Laurea magistrale in Scienze motorie preventive ed adattate

(Laurea magistrale in Scienze dello sport individuali e squadra,

Laurea magistrale in Scienze dello sport e montagna)

Team sports match analysis

Thursday 10/10/2019 14÷15:30

Luca P. Ardigò Ph.D.

A class within an ten-class module

A sample scientific article

Journal of Sports Sciences, 2015
Vol. 33, No. 17, 1853–1858, http://dx.doi.org/10.1080/02640414.2015.1015150

Routledge
Taylor & Francis Group

A low-cost method for estimating energy expenditure during soccer refereeing

LUCA PAOLO ARDIGÒ[1], JOHNNY PADULO[2], ANDREA ZULIANI[3] & CARLO CAPELLI[1]

[1]*Department of Neurological and Movement Sciences, School of Exercise and Sport University of Verona, Verona, Italy,* [2]*Tunisian Research Laboratory "Sports Performance Optimization", National Center of Medicine and Science in Sport, Tunis, Tunisia and* [3]*Italian Football Federation (FIGC), Italian Referees Association (AIA), Roma, Italy*

(*Accepted 1 February 2015*)

Football referees

- They cover total match distances similar to those covered by the most active players (i.e., midfielders; ≈10.5 vs. ≈11.3 km), while being much older (≈37.1 vs. ≈26.4 y).

VS.

Helsen et al., 2004; Ardigò, 2010

Match analysis

DALLAS MAVERICKS (34-33)

			FIELD GOALS				REBOUNDS									
	POS	MIN	FGM-A	3PM-A	FTM-A	+/-	OFF	DEF	TOT	AST	PF	ST	TO	BS	BA	PTS
W. Matthews	F	37:36	1-8	1-3	2-2	+19	0	5	5	2	3	0	1	0	2	5
C. Parsons	F	37:24	9-14	5-9	1-2	+2	2	7	9	4	2	3	2	1	0	24
D. Nowitzki	C	28:00	8-18	1-5	6-7	+24	1	10	11	1	3	0	1	2	1	23
D. Williams	G	30:07	6-11	1-4	2-2	+4	0	0	0	5	4	1	1	1	1	15
R. Felton	G	31:53	4-11	1-4	0-1	+17	1	2	3	12	2	3	5	0	2	9
D. Lee		26:06	6-8	0-0	0-0	+7	2	5	7	0	5	0	2	1	0	12
D. Harris		20:33	5-8	0-2	2-2	-8	0	2	2	1	3	1	2	0	0	12
J. Anderson		07:53	0-1	0-1	1-2	+6	0	3	3	1	1	1	0	1	0	1
J.J. Barea		14:29	2-6	0-1	0-0	-8	0	0	0	4	2	0	0	0	1	4
Z. Pachulia		05:59	1-2	0-1	0-0	-8	0	2	2	0	1	0	0	0	0	2
S. Mejri	DNP - COACH'S DECISION															
D. Powell	DNP - COACH'S DECISION															
C. Villanueva	DNP - COACH'S DECISION															
Total		**240**	**42-87**	**9-30**	**14-18**		**6**	**36**	**42**	**30**	**26**	**9**	**14**	**6**	**7**	**107**
			48.3%	30.0%	77.8%		**TEAM REBS:** 13						**TOTAL TO:** 15			

- Match analysis represents a continuum of sport statistics.

Match analysis/2

SPEED AND DISTANCE

PLAYER | TEAM

Speed and Distance: Statistics that measure the distance covered and the average speed of all movements (sprinting, jogging, standing, walking, backwards and forwards) by a player while on the court.

Page 1 of 10 | 476 Rows

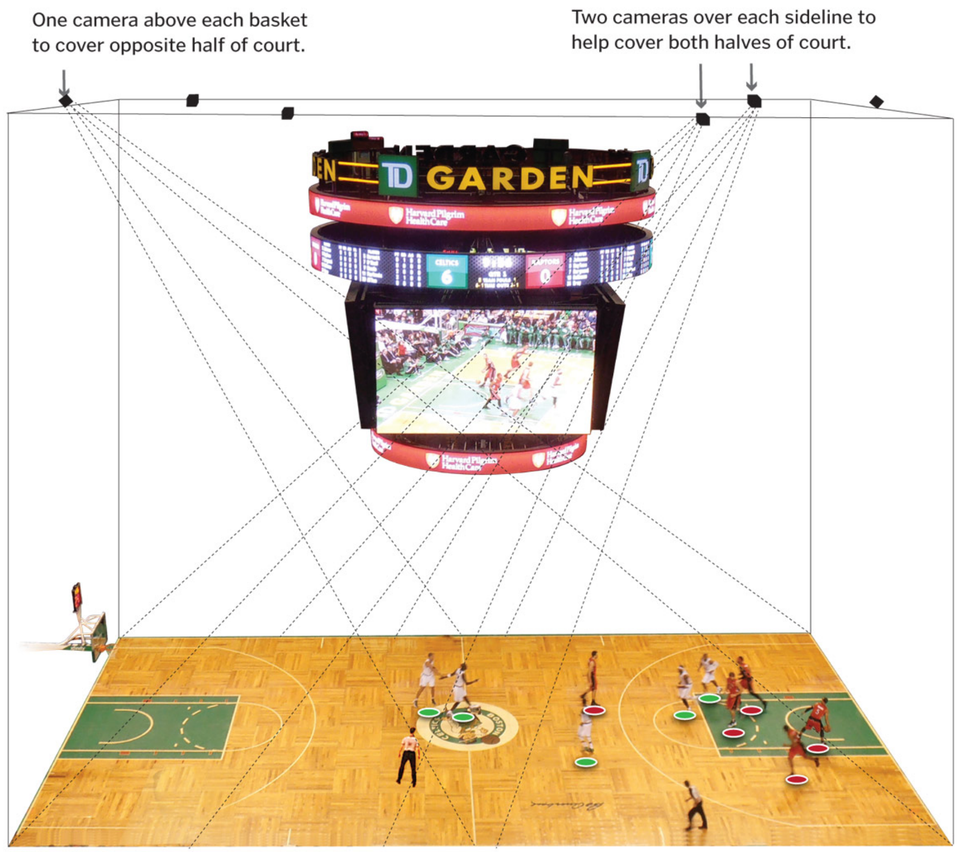
Player	Team	GP	W	L	MIN	Dist. Feet	Dist. Miles	Dist. Miles Off	Dist. Miles Def	Avg Speed	Avg Speed Off	Avg Speed Def
Dahntay Jones	CLE	1	0	1	42.4	15576.0	2.95	1.49	1.46	4.27	4.23	4.21
Jimmy Butler	CHI	67	37	30	36.9	13917.1	2.64	1.42	1.21	4.28	4.61	3.95
Brandon Knight	PHX	52	16	36	36.0	13666.0	2.59	1.40	1.18	4.31	4.70	3.91
CJ McCollum	POR	80	44	36	34.8	13576.9	2.57	1.48	1.09	4.45	5.01	3.87
Gordon Hayward	UTA	80	38	42	36.2	13392.1	2.54	1.46	1.08	4.20	4.61	3.75
Kentavious Caldwell-Pope	DET	76	41	35	36.7	13385.5	2.54	1.35	1.19	4.14	4.41	3.87
Nicolas Batum	CHA	70	41	29	35.0	13246.8	2.51	1.38	1.12	4.29	4.71	3.87
Damian Lillard	POR	75	40	35	35.7	13043.0	2.47	1.41	1.06	4.14	4.64	3.65
Khris Middleton	MIL	79	33	46	36.1	12992.8	2.46	1.29	1.17	4.09	4.40	3.78
Kemba Walker	CHA	81	47	34	35.6	12992.8	2.46	1.39	1.07	4.13	4.65	3.62

W/SportVU

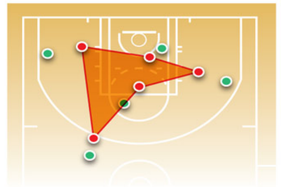
Match analysis/3

How SportVU technology works

1 Fixed to a metal catwalk, six small cameras are used to track the movements of all 10 players, the three referees, and the ball. The cameras use Israeli missile-tracking technology.



2 Optical recognition software picks up jersey numbers and captures every pass, shot, and dribble. Images are collected 25 times per second.



3 The software produces data based on player movement in categories such as drives, speed, and distance, touches per possession, catch and shoot, and defensive impact.

Teams Receive advanced metrics that go beyond basic stats.

Fans Get more general information to track the game live.

4 The play-by-play data can be delivered in a report within 90 seconds of a play. Both team personnel and casual fans have these live statistics at their disposal.

SOURCE: SportVU

JAMES ABUNDIS, LUKE KNOX/GLOBE STAFF

Match analysis team sports

Indoor

Match analysis team sports/2

Match analysis team sports/3

Outdoor

Match analysis team sports/4

Outdoor/2

Low-cost match analysis of football refereeing

1 Hz,
€ 161.82 (+14 shipping 07/10/2019)

Low-cost match analysis of football refereeing/2

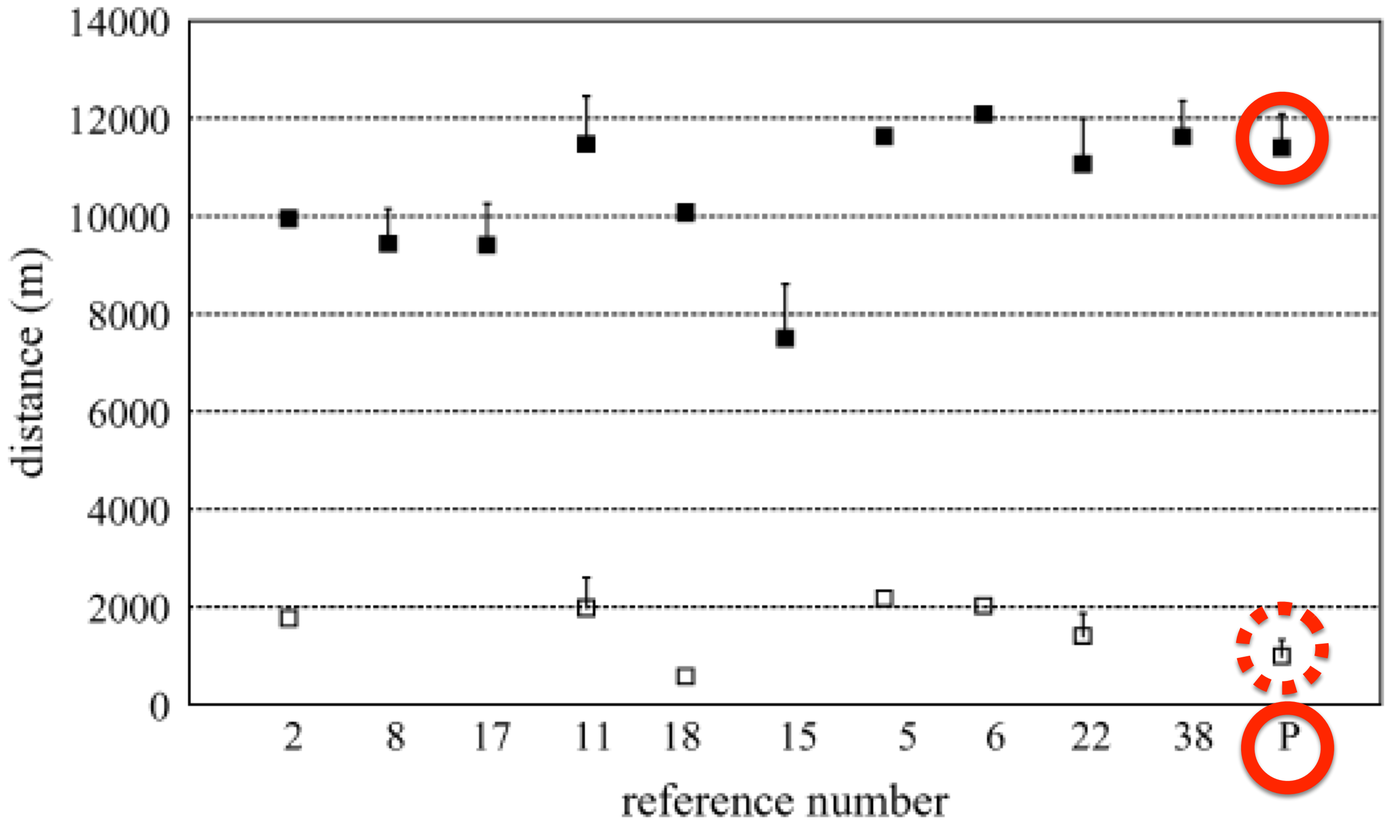
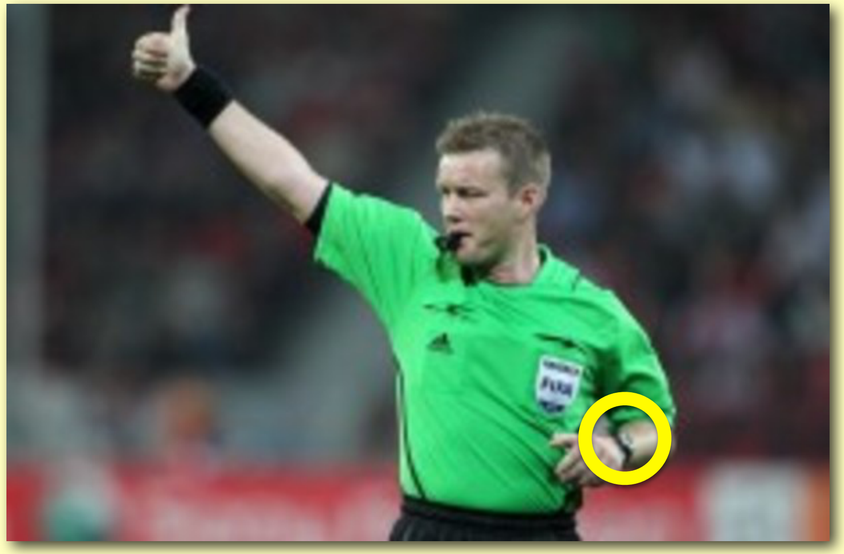


Figure 1. Referees' total match distance (black squares) and high-quality running (empty squares) from literature and present study (references in chronological order and P: present study; average + positive standard deviation [when given]; same in Figures 2, 3, and 4).

Ardigò, 2010

Low-cost match analysis of football refereeing/3

- Approach's limitation: players are (were) not allowed to wear external measuring devices;



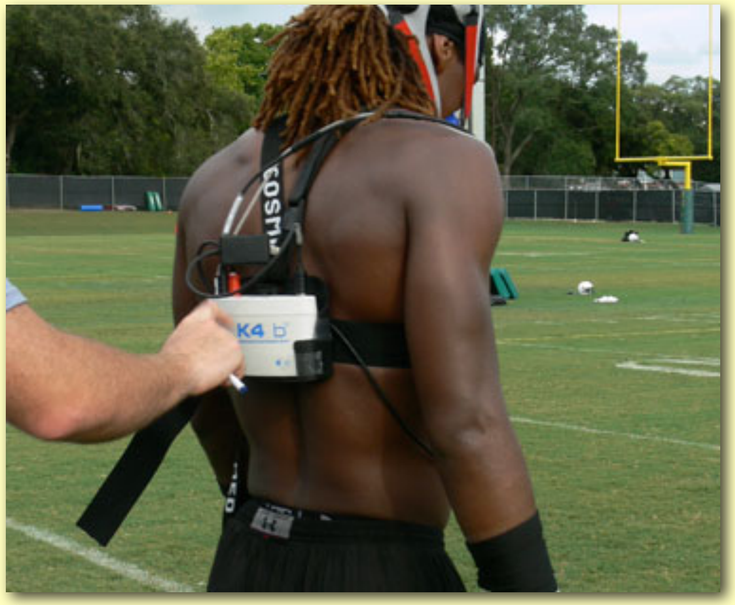
- study's outcome: a low-cost methodology may be chosen by a broader number of referees to evaluate functionally their physical abilities.

Match analysis: next level

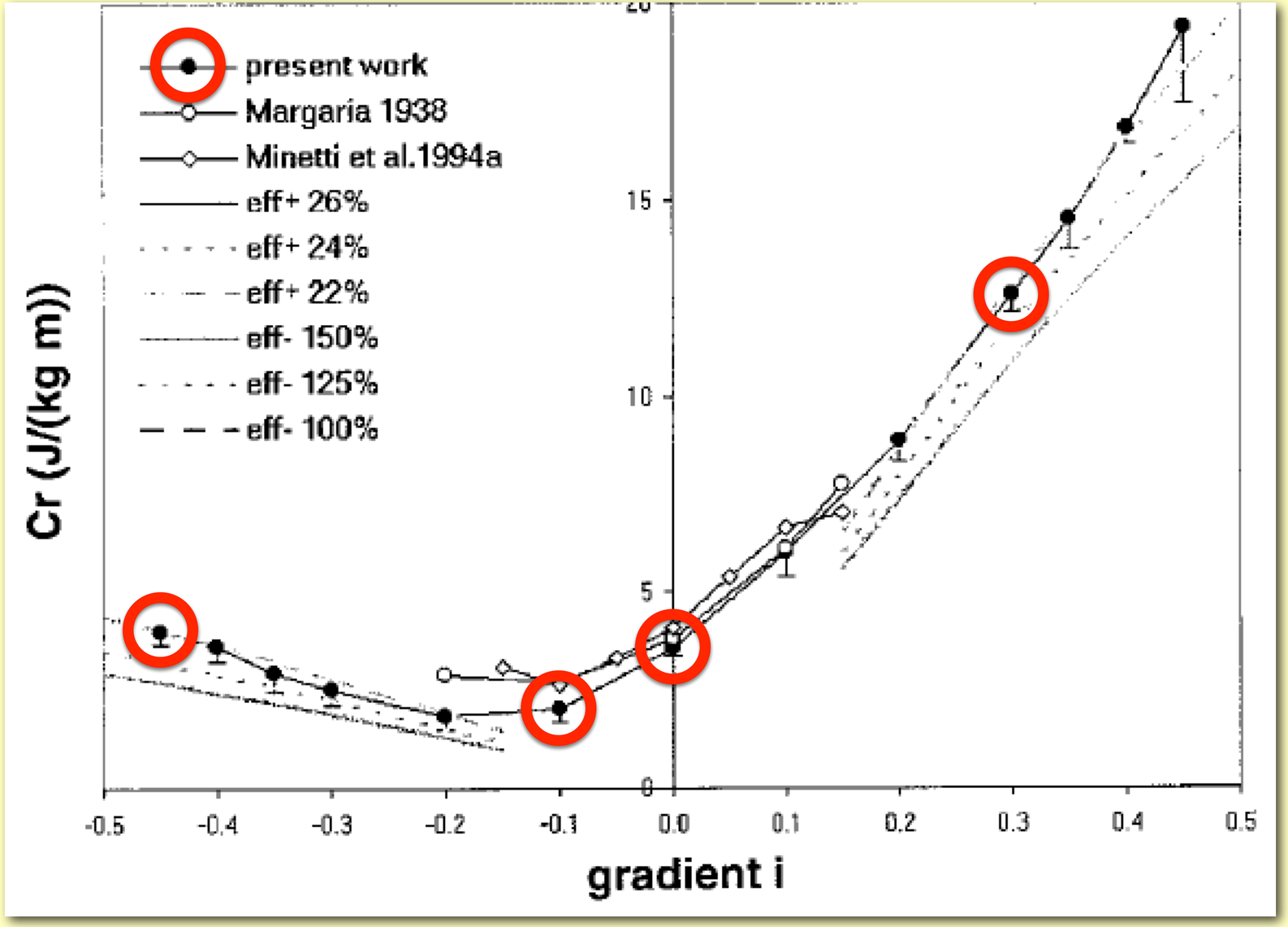
- Total and high-speed covered distances not enough anymore;
- new focus by both trainers and scientists on acceleration;
- trainers: acceleration = capability to achieve required speed;
- scientists: acceleration paradigm, acceleration <- force <- muscles <- metabolic expenditure (see accelerometers use widespread diffusion).

Acceleration and metabolic expenditure

- How to measure metabolic expenditure during physical activity?
- Portable metabograph??
- Bulky, fragile, expensive!!!



Acceleration and metabolic expenditure: missing link



$$\mathrm{Cr}_i = 155.4i^5 - 30.4i^4 - 43.3i^3 + 46.3i^2 + 19.5i + 3.6 \quad (\mathrm{R}^2 = 0.999)$$

Minetti et al., 2002

Acceleration and metabolic expenditure: missing link/2

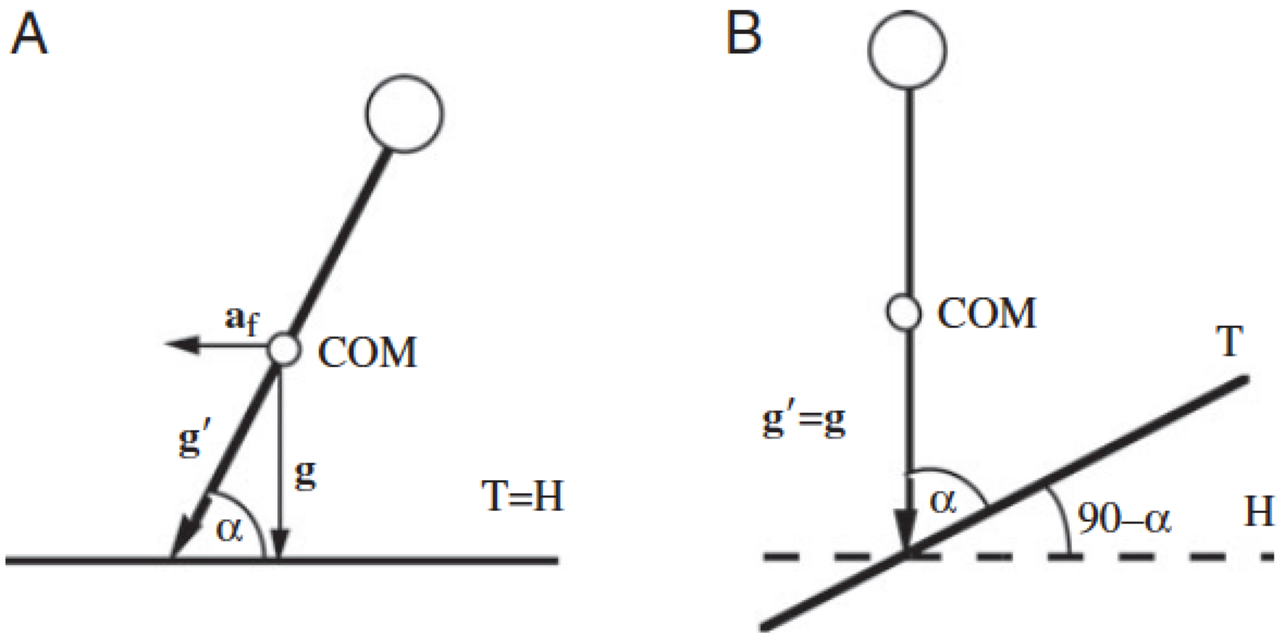
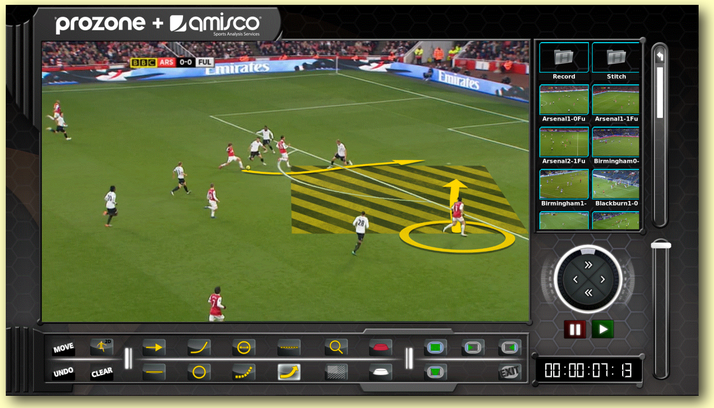


Fig. 1. Simplified view of the forces acting on a runner. The subject is accelerating forward while running on flat terrain (A) or running uphill at constant speed (B). The subject's body mass is assumed to be located at the centre of mass (COM); $\mathbf{a}_f$=forward acceleration; **g**=acceleration of gravity; $\mathbf{g}'=(\mathbf{a}_f^2+\mathbf{g}^2)^{0.5}$ is the acceleration resulting from the vectorial sum of $\mathbf{a}_f$ plus **g**; T=terrain; H=horizontal; α (=arctan $\mathbf{g}/\mathbf{a}_f$) is the angle between runner's body and T; the angle between T and H is $\alpha'=90-\alpha$. (Modified from di Prampero et al., 2002.)

di Prampero et al., 2005

Acceleration and metabolic expenditure: practice

- Need for higher-sampling frequency (i.e., > 1 Hz).
- Available options: video-based systems (very expensive), accelerometer-enhanced GPS receivers (expensive), high-frequency cinematography (need for much human work) or?



Osgnach..., & di Prampero, 2010 @25 Hz (players, matches)

Gaudino et al., 2013 @5 Hz (+accel @100 Hz, players, sprints)

Buglione & di Prampero, 2013 @210 Hz (players, shuttle sprints)

Acceleration and metabolic expenditure: practice/2

- "or"?
- Trip recorder (among main applications photographs' geo-tagging).

5 Hz,
€ 47.83 (? shipping 07/10/2019)

Acceleration and metabolic expenditure: data analysis

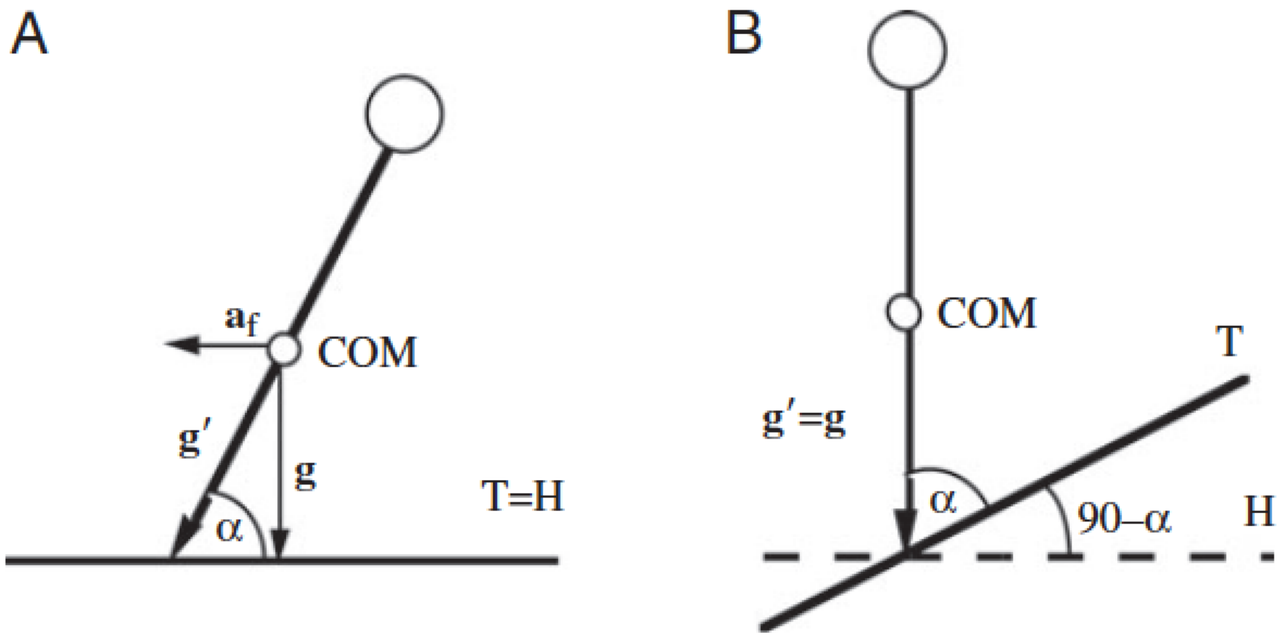


Fig. 1. Simplified view of the forces acting on a runner. The subject is accelerating forward while running on flat terrain (A) or running uphill at constant speed (B). The subject's body mass is assumed to be located at the centre of mass (COM); $\mathbf{a}_f$=forward acceleration; **g**=acceleration of gravity; $\mathbf{g}'=(\mathbf{a}_f^2+\mathbf{g}^2)^{0.5}$ is the acceleration resulting from the vectorial sum of $\mathbf{a}_f$ plus **g**; T=terrain; H=horizontal; α (=arctan $\mathbf{g}/\mathbf{a}_f$) is the angle between runner's body and T; the angle between T and H is $\alpha'=90-\alpha$. (Modified from di Prampero et al., 2002.)

Acceleration and metabolic expenditure: data analysis/2

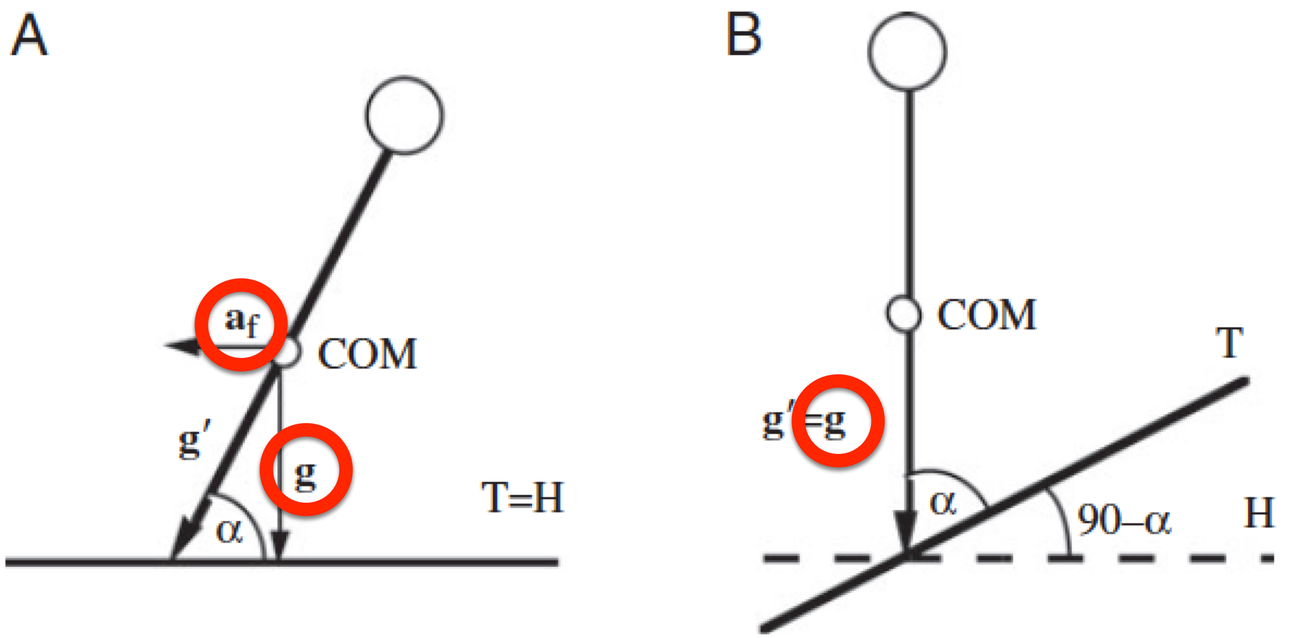


Fig. 1. Simplified view of the forces acting on a runner. The subject is accelerating forward while running on flat terrain (A) or running uphill at constant speed (B). The subject's body mass is assumed to be located at the centre of mass (COM); a_f=forward acceleration; g=acceleration of gravity; $g'=(a_f^2+g^2)^{0.5}$ is the acceleration resulting from the vectorial sum of a_f plus g; T=terrain; H=horizontal; α (=arctan g/a_f) is the angle between runner's body and T; the angle between T and H is $\alpha'=90-\alpha$. (Modified from di Prampero et al., 2002.)

$$C = (155.4 \cdot ES^5 - 30.4 \cdot ES^4 - 43.3 \cdot ES^3 + 46.3 \cdot ES^2 + 19.5 \cdot ES + 3.6)\ EM \cdot KT$$

$$ES = \tan\ (90 - \arctan\ g/a)$$

$$EM = (a^2/g^2 + 1)^{0.5}$$

Acceleration and metabolic expenditure: data analysis/3

- Conversion of the C values (recorded @5 Hz, i.e., every 0.2 s) into the corresponding mass-normalised, metabolic power values (nMP [W/kg]) by multiplying C by its corresponding speed s ($nMP = C \cdot s$);

Acceleration and metabolic expenditure: data analysis/3

- conversion of the so-obtained nMP values into instantaneous, activity, mass-normalised, energy consumption (nMECi) values [J/kg] by multiplying nMP by 0.2 s ($nMECi = nMP \cdot 0.2$);

Acceleration and metabolic expenditure: data analysis/3

- calculation of the energy consumption due to activity (nMEC [kJ]) over the entire match by adding together all the aforementioned instantaneous values multiplied by the mass of the participant m (nMEC = (SUM(nECi) · m)/1,000);
- calculation of the mass-normalised, total energy consumption (tMEC [kJ/kg]) by adding the energy due to resting metabolism – assumed to be equal to 80 W over the entire match duration d (tMEC = nMEC/m + ((80/1,000) · d)).

Acceleration and metabolic expenditure: results

Table I. Equivalent distance (*ED*), total distance (*TD*), equivalent distance index (*EDI*), absolute/activity metabolic energy consumption (*nMEC*) and mass normalized/total metabolic energy consumption (*tMEC*), coefficient of variation (CV), minimum (Min) and maximum (Max) over match and compared with results from Osgnach et al. (2010) (right columns).

	Current study					Osgnach et al. (2010)			
	Mean ± *s*	CV (%)	Min	Max		Mean ± *s*	CV (%)	Min	Max
ED (m)	13,788 ± 1151	8	11478	15652	vs.	13,166 ± 1415	11	10067	16,845
TD (m)	13,112 ± 1225	9	10861	15153	vs.	10,950 ± 1044	10	8683	13,533
EDI	1.05 ± 0.05	5	0.92	1.09	vs.	1.20 ± 0.03	3	1.13	1.33
nMEC (kJ)	4729 ± 608	13	3817	5687	vs.	4633 ± 498	11		
tMEC ($kJ \cdot kg^{-1}$)	74 ± 8	10	61	86	vs.	67*			

Note: * = value estimated from average match duration and subjects mass.

- Referees' both net match energy consumption nMEC and total mass-normalised energy consumption tMEC higher than players' ones.

Acceleration and metabolic expenditure: outcome

- Estimate of the energy expenditure of soccer referees during official matches even by using a very low-cost device as a commercial 5 Hz GPS receiver -> metabolic energy management planning feasible (within soccer refereeing clearly chaotic setting) -> subject/activity-specific diet & training planning feasible.

Match analysis: next-next level

- Team (in addition to single players) as a single subject for testing/conditioning (i.e., as a single body to coach);
- e.g., specific pitch area coverage, "short"/"low" or "long"/"high" team layout, time to counter attack/half court line forward cross, time to come back to defence/half court line backward cross...

Match analysis: current technological advances

- IMU-based or locally-enhanced GPS receivers;
- Galileo.

VERTICAL ACCURACY

	Urban Canyon #1	Urban Canyon #2
GPS	331.9m	76.2m
GPS+GLONASS	42.9m (13%)	7.6m (10%)
GPS+Galileo	10.7m (3%)	5.4m (7%)
GPS+GLONASS+Galileo	43.0m (13%)	24.7m (32%)

Positive numbers indicate improvement over GPS.

	Indoor #1	Indoor #2
GPS	278.7m	70.3m
GPS+GLONASS	68.4m (25%)	11.8m (17%)
GPS+Galileo	24.6m (9%)	10.1m (14%)
GPS+GLONASS+Galileo	64.0m (23%)	15.8m (23%)

Positive numbers indicate improvement over GPS.

HORIZONTAL ACCURACY

	Urban Canyon #1	Urban Canyon #2
GPS	182.3m	46.1m
GPS+GLONASS	26.9m (15%)	4.9m (11%)
GPS+Galileo	3.6m (2%)	-0.1m (0%)
GPS+GLONASS+Galileo	35.0m (19%)	8.1m (17%)

Positive numbers indicate improvement over GPS.

	Indoor #1	Indoor #2
GPS	243.7m	83.2m
GPS+GLONASS	73.3m (30%)	9.8m (12%)
GPS+Galileo	3.1m (1%)	8.6m (10%)
GPS+GLONASS+Galileo	76.6m (31%)	16.2m (19%)

Positive numbers indicate improvement over GPS.

Match analysis: current technological advances/2

20 Hz

50 Hz

Match analysis: new rule

FIFA
For the Game. For the World.

TO THE MEMBERS OF FIFA

Circular no. 1494

Zurich, 8 July 2015
SG/sco/ovo

Approval of Electronic Performance and Tracking System (EPTS) devices

Dear Sir or Madam,