The 30-15 Intermittent Fitness Test – two decades of learnings

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High-intensity interval training | HIIT prescription | athletes testing | athlete profiling | anaerobic speed reserve

Headline

After about 20 years of use, the 30-15_{IFT} is now being implemented all over the world, mainly in team, racquet and combat sports. The increasing number of publications and constant google searches for more than 15 years attest to the continued and progressing interest for the test from both academics and practitioners (Figure 1). The test increasingly appeals to more athletes, coaches, and sports scientists within various clubs, institutes, and National teams. It continues to be one of the most-used field tests to both assess high-intensity intermittent running performance and program high-intensity interval training (HIIT) (Laursen & Buchheit, 2018; Bok & Foster, 2021).

Aim. This paper provides an update about the $30-15_{IFT}$ after >20 years of use, from its history, its conceptual and physiological bases to its progressive dissemination as a testing and high-intensity interval training (HIIT) prescription tool across almost every run-based sport and research institution. Following the 10-year review published in 2010 (Buchheit, 2010), we also provide some updated elements to support its use over alternative field tests, together with new guidelines in terms of its programming within the training microcycle. Finally, we report typical changes in the final velocity achieved during the $30-15_{IFT}$ (V_{IFT}) that are to be expected following short HIIT cycles and provide simple methodological considerations to assess meaningful changes in individual athletes.

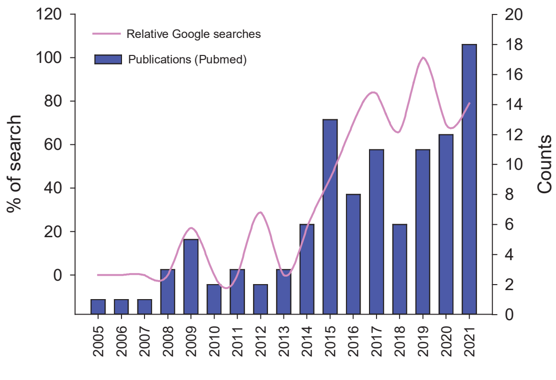

Fig. 1: Number of publications (limited to PubMed - there are today many journals not indexed such as SPSR, where the $30-15_{IFT}$ has also been mentioned/examined) and Google search trends since 2007. Google trends are relative (%) to the highest number of searches (Jan 2019). A value of 100 is the peak popularity for the term. A value of 50 means that the term is half as popular. A score of 0 means there was not enough data for this term.

The Test. The $30-15_{IFT}$ is an incremental, intermittent running test designed to improve run-based high-intensity interval training (HIIT) prescription (Buchheit, 2005). It consists of 30-s shuttle runs interspersed with 15-s passive recovery periods. The initial velocity is set at 8 or 10 km/h for the first 30-s run and is increased by 0.5 km/h every 45-s stage thereafter. The calculation of targeted distances to run during each 30-s period takes into account the fact that the energy cost of one change of direction (COD) is increased when running speed is increased (Figure 2). During the 15-s recovery period, the subjects walk in the forward direction to join the closest line (at the middle or at one end of the running area, depending on where the previous run stopped). This determines the start line of the next run stage. The test ends when an athlete can no longer maintain the imposed running speed or when he or she fails to reach the 3-m zone around each line at the moment of the audio signal on three consecutive occasions. The final velocity of the last successfully completed stage is taken as the V_{IFT}.

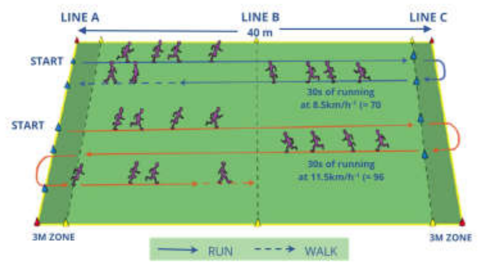

Fig. 2: Diagram of the layout of the $30-15_{IFT}$ (original 40-m version and Ice). For the 28 m version, turning zones at the extremity of the court and the zone in the middle (14 m) are reduced to 2 m. For the 'straight-line' version on a 400 m track, cones are placed every 20 m and players change direction after each 30 s effort only. Detailed protocols are accessible here in English, French and Spanish

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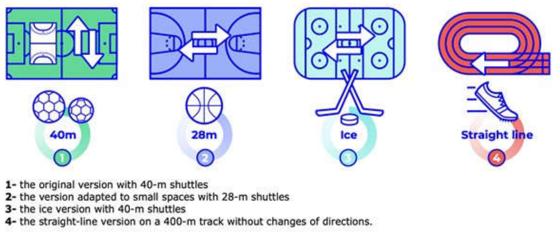
History. The full history of the test, from its inception to multiple trials on the field and the first drafts of the manuscript submitted simultaneously in English to the Journal of Strength & Conditioning Research (December 2004, accepted early in 2007 and published in December 2008 (Buchheit, 2008)) and in French to "Les approches du Handball" (Buchheit, 2005) is well detailed in the 10-y review (Buchheit, 2010). Of interest, long before the final publication, the audio of the test was recorded in my toilets (!!!) during the summer of 2000,



using one of the first portable digital recorders. At that time, I was sharing the .mp3 file via Dropbox to anyone reaching out, and the test was largely disseminated organically. While I obviously started with French, soon the Aussies asked for an English version of the audio. “Be careful” (when changing for the first time the starting line from A to B, when initiating the stage at 10.5 km/h) with a pretty strong French accent became the testing norm for many AFL teams from 2007 onwards (and coaches and players taking the p*** every time I would meet one of them). Those original recordings are still part of the soundtracks available in the App, which was released in the summer of 2018 (which received about 2000 downloads during the first weeks of release). The App now includes audio tracks in Spanish as well, and various other versions of the test, including different starting speeds (8 vs. 10 km/h) or adapted protocols such as running over 28-m shuttles (Basketball court) (Haydar, Al Haddad, Ahmadi, & Buchheit, 2011) or along a track and field 400-m track (no CODs), and of course, the Ice-Hockey version of the test (Buchheit, Lefebvre, Laursen, & Ahmaidi, 2011; Besson, Buchheit, Praz, Deriaz, & Millet, 2013). The test now also has its own blog, Twitter and Instagram accounts where people can find the latest news in terms of publications, practical application and users' testimonies.

Why 30-15$_{\mathbf{IFT}}$? In fact, it is impossible to define a single and common typical work duration and work/rest ratio that mimics intermittent sports: every sport is different, and more importantly, there are so many variations within the same sport (e.g., playing position, player profile) that it is clearly impossible to design a test that would be truly sport-specific to any sport and athlete in the world. Therefore, the durations of exercise and recovery periods of the test were rather chosen with regard to how HIIT with short intervals is prescribed in most intermittent sports (Laursen & Buchheit, 2018), and according to various physiological considerations (Buchheit, 2008). The 30-s exercise time is close to the time of cardiorespiratory on-response kinetics at exercise onset (Davies, Di Prampero, & Cerretelli, 1972) and is also the time for which oxyhemoglobin (HbO2) resources have been shown to be consumed during intense exercise (McCully, Iotti, Kendrick, Wang, Posner, Leigh, et al., 1994). Phosphagen system requires about 20-30 seconds to replenish about 50% of the phosphocreatine stores (Harris, Edwards, Hultman, Nordesjo, Nylind, & Sahlin, 1976); therefore the 15-s recovery period allows sufficient but incomplete PCr recovery in between the repeated efforts (Bangsbo, Norregaard, & Thorso, 1991), as it happens during HIIT with short intervals (Laursen & Buchheit, 2018).

Physiological and locomotor responses to the 30-15$_{\mathbf{IFT}}$. According to the HIIT Science terminology (Laursen & Buchheit, 2018), the metabolic and locomotor demands of the $30-15_{IFT}$ can be divided into three main components, 1) aerobic energy contribution 2) anaerobic (lactic) energy contribution, and 3) neuromuscular load.

Aerobic contribution. The total duration of the $30-15_{IFT}$ is approximately 21 ± 2 min (15-24 min) where the athlete maintains >90% VO_{2max} ($T@VO_{2max}$) for 2 min 30 s ± 2 min (1–4 min) (Figure 3) (Buchheit, & Brown, 2020; Kaufmann et al., 2020a). The aerobic contribution to the total energy production of the entire test was shown to be 67%, which is likely higher than the 49% and 48% reported for the Yo-YoIR1 and Yo-YoIR2 respectively (Kaufmann et al., 2020a; Kaufmann, Hoos, Kuehl, Tietz, Reim, & Fehske, et al., 2020b).

Anaerobic contribution. The anaerobic a-lactic share was shown to be close to 30% (Kaufmann, Beneke, Richard, Hanna, & Olaf, 2020a). This important contribution is related to the repeated recovery phases of the test, that allow athletes to rely a lot more on their PCr usage/recovery cycle than during a continuous version of the test (where PCr resynthesis would be almost absent, and a-lactic contribution <10% (Kaufmann et al., 2020a)).

Despite blood lactate levels ranging from 9.2 ± 1.3 mmol/L (average V_{IFT}: 18.3 km/h) (Kaufmann et al., 2020a) to 12.3 ±

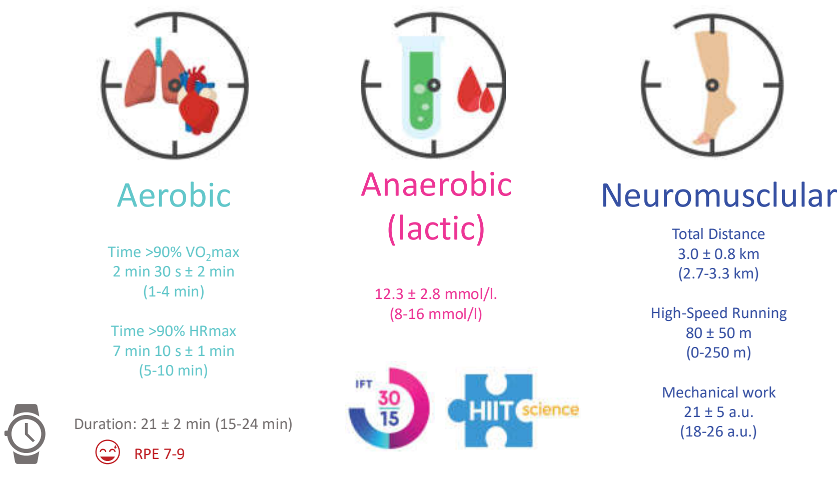


Fig. 3: Physiological responses to the $30-15_{IFT}$ (Buchheit, & Brown, 2020) HR: heart rate. TD: total distance. HSR: high-speed running (>19.8 km/h), BL: Blood lactate, MW: mechanical work, RPE: rate of perceived exertion (0-10 scale).

2.8 mmol/L (8–16 mmol/L, average V_{IFT}: 19.5 km/h) (Buchheit, 2008; Buchheit & Brown, 2020, Haydar et al., 2011) at exhaustion, the glycolytic anaerobic (lactic) contribution to the entire exercise energy turnover was shown to be less than 5% (Kaufmann et al., 2020a).

Neuromuscular load. Despite the lack of information on the actual level of muscle recruitment and musculoskeletal strain during the test per se (for which electromyography for example would be required), neuromuscular load can be indirectly inferred from measures of external load – namely its locomotor demands (Buchheit & Barrett, 2020) - with the greater the demands, the likely greater the neuromuscular load. For a team with an average V_{IFT} of 19.5 km/h for example, the total distance covered is about 3.0 ± 0.8 km (2.7–3.3 km), with 80 ± 50 m (0–250 m) covered at high speed (>19.8 km/h). The amount of mechanical work, representing acceleration, deceleration and COD efforts together is around 20 a.u. (which is about 50-60% of one soccer match half).

In conclusion, the metabolic and locomotor loads of the test are rather low in comparison with typical training (60-80%) and match (<40%) loads. For this reason we suggested that the test can be simply embedded into a training session (Figure 4), and considered as a training sequence in between other technical elements (Buchheit & Brown, 2020) (Figure 4).

Fig. 4: Within-session example integrating the 30-15$_{IFT}$. Drill 1: low-intensity possession games (with at least 6 to 8 players per team to decrease mechanical work). Drill 2: Tactical-oriented work such as directed games (the coach regularly stops the play to provide feedback to different player lines or different teams) or set pieces. Drill 1 + 2 = TD: 3-4 km, no HSR and MW 20 a.u. Top up: additional 50-200m of HSR with low metabolic demands (HIIT Type 6) such as 2-4 x box-to-box runs within 12-15s interspersed with >30s of rest, with more repetitions for those not having performed above 19km/h on the test.

Why choose the 30-15$_{\mathbf{IFT}}$: Insights from the test protocol. When it comes to assessing cardiorespiratory fitness in the field, there are many tests available among the following (Laursen & Buchheit, 2018; Bok and Foster, 2021): the University of Montreal Track Test (UM-TT) (Léger, & Boucher, 1980), the Multistage Fitness Test (MSFT) (Léger, Mercier, Gadoury, & Lambert, 1988), the Gacon 45-15 test (Assadi, & Lepers, 2012), and the Yo-Yo Intermittent Recovery Tests, with two variations, i.e., Level 1 (Yo-Yo IR1) and Level 2 (Yo-Yo IR2) (Krustrup, Mohr, Amstrup, Rysgaard, Johansen, Steensberg, et al., 2003; Bangsbo, Iaia, & Krustrup, 2008). The UM-TT involves linear and continuous runs; it essentially allows assessing of one component of athletes' locomotor profile (i.e., maximal aerobic speed, MAS), which is a combination of both maximal oxygen uptake and running economy. The MSFT tends to assess MAS as well, but since it involves continuous efforts over 20-m shuttles, it's in fact a change of direction (COD) ability-related MAS that is captured by the final speed. The 45-15 involves repeated and intermittent efforts over straight line runs, which provides information about inter-effort recovery, but not COD abilities. The two Yo-Yo tests and the $30-15_{IFT}$ are therefore the only two types of intermittent and shuttle-based protocols; they involve simultaneously repeated intermittent efforts and CODs, which are the physiological capacities that seem to matter when testing intermittent sport athletes. While the peak speeds reached in the different Yo-Yo tests (e.g., $V_{Yo-YoIR1}$ for the Yo-Yo Intermittent Recovery Level 1) and the speed reached at the of the $30-15_{IFT}$ (V_{IFT}) have shown to be strongly correlated (Buchheit, & Rabbani, 2014) (Figure 5), their main determinants might differ slightly. The fact that V_{IFT} is clearly faster than $V_{Yo-YoIR1}$ makes it more related to maximal sprinting speed (MSS) and the anaerobic speed reserve (ASR, see section 7).

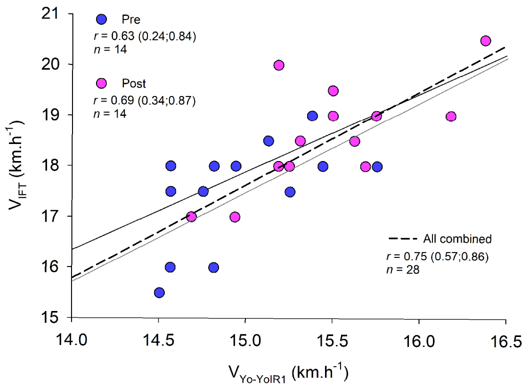


Fig. 5: Relationship (correlation coefficient, r, 90% confidence limits) between the final speeds reached at the end of the Yo-Yo Intermittent Recovery Test Level 1 ($V_{Yo-YoIR1}$) and the 30-15 Intermittent Fitness Test (V_{IFT}). Pre and post data refer to tests programmed before and after a HIIT training intervention (which didn't affect the relationship between both tests – both data sets were pooled to increase sample size) (Buchheit, & Rabbani, 2014).

Why choose the 30-15$_{\mathbf{IFT}}$: Insights from its locomotor and energetic determinants. The locomotor determinants of V_{IFT} were initially examined using correlation analyses (Buchheit, 2008; Buchheit & Mendez-Villanueva, 2013) in young team sport players. Preliminary results showed that V_{IFT} is well correlated with MAS, acceleration and changes of direction abilities (Buchheit, 2008). Also, while MAS likely accounts for a very large portion of the V_{IFT} performance, a faster MSS for a given MAS (which is therefore associated with a greater ASR), allows for a faster V_{IFT} (Buchheit, 2010; Buchheit & Mendez-Villanueva, 2013). While beyond the scope of the present study, the ASR is defined as the difference between an athlete's MSS and MAS. It reflects a work capacity in the high-intensity domain, and directly affects athletes' tolerance to exercise above MAS – with the greater the proportion of the ASR used, the lower the exercise tolerance (Blondel et al., 2001; Buchheit, Hader, & Mendez-Villanueva, 2012; Buchheit, & Laursen, 2013a; Sandford, Laursen & Buchheit, 2021).

To further highlight the impact that a player's locomotor profile has on V_{IFT}, we present here an energetics model (Vassallo et al., 2021) to simulate the mechanical and energetic locomotor demands of the 30-15$_{IFT}$ and more precisely, the expenditure and repletion of finite work capacity (W', "Wprime") during the test in four player profiles, each possessing distinct locomotor profiles: 1) Fit and Fast; 2) Fit and Slow; 3) Less Fit and Fast; 4) Less Fit and Slow (Table 1). These profiles were believed to be representative of the possible distributions in elite soccer, with examples of the corresponding positions provided for context (Buchheit, Vassallo, & Waldron, 2021).

Table 1: Selected player profiles

	Speed Profile						Energetic Profile	
	MSS (km/h)	MAS (km/h)	ASR	V_{IFT} (km/h)	CS (km/h)	*D´* (m)	CP (W)	*W´* (kJ)
Fit and Fast (Full backs)	34.0	18.5	15.5	20.5	15.5	320	515	38.0
Fit and Slow (Midfield)	29.0	18.5	10.5	20.0	16.0	220	530	28.0
Less Fit and Fast (Central defenders, Attackers)	35.0	16.0	19.0	19.0	13.2	350	440	42.0
Less Fit and Slow	30.0	16.0	14.0	18.5	13.8	300	460	32.0

MSS = maximal sprinting speed; MAS = maximal aerobic speed; ASR = anaerobic speed reserve; V_{IFT} = velocity achieved upon termination of the 30-15 Intermittent Fitness Test; CS = critical speed; D´ = finite distance capacity above CS; CP = critical power; *W'* = finite work capacity above CP.

Speed and Energetic Parameters: Raw GPS velocity data were modelled to over-ground mechanical power using a validated energetics model (Gray et al., 2020). The critical speed or power (CS/CP) and finite distance or work capacity (*D'*/*W'*) are two mathematically derived parameters that integrate respiratory, metabolic and contractile physiological profiles (Poole et al., 2016), suggested to be important to the application of intermittent sport, such as soccer (Jones & Vanhatalo, 2017). The CS (m/s) or CP (W) has been identified as the 'gold standard' of the maximal metabolic steady state, a critical fatigue threshold reflecting the highest work rate sustained by oxidative metabolism (Jones et al., 2019). The *D'* or *W'* is the finite distance (m) or work capacity (kJ) available above the CS or CP, respectively. Full depletion of W´ has been shown to be coincident with exhaustion in cycling (Skiba et al., 2012; Townsend et al., 2017) and flat over-ground intermittent running (Vassallo et al., 2020), largely attributable to the attainment of a "critical" metabolic milieu (i.e. ↑ intramuscular metabolites, ↑ blood lactate, ↑ VO_2 slow component, ↓ muscle Ph, ↓ glycogen, ↓ PCr) (Chidnok et al., 2013). The W´ is thus predictive of supra-CP work capacity in the severe-intensity exercise domain, with direct application to HIIT. When mechanical power output is > CP, *W'* is expended; when power output is < CP, *W'* is reconstituted, such that the balance of *W'* remaining (W'_{BAL}) may be quantified at any point in time (Skiba et al., 2012, 2015, 2021).

As shown in Figure 6, near-complete depletion of W'_{BAL} (± 0.8 kJ) for all 4 player profiles was coincident with terminating the test upon exhaustion. With the degree of expenditure (and repletion) of W'_{BAL} during high-intensity intermittent running being directly related to players' energetic profiles (CP and W´, see Table 1), this modelled example corroborates previous theoretical demonstrations of the determinants of V_{IFT} (Buchheit, 2010). Of note, W'_{BAL} may not equate perfectly to 0 kJ at exhaustion (% remaining W'_{BAL} of -1.5 to 3.0%, Figure 6), explaining athlete motivation to either stop ahead of complete exhaustion or push beyond the sensation of "uncomfortableness" despite severe disruptions to homeostasis. Furthermore, this confirms that for two players with a similar MAS, a greater ASR (via faster MSS) allows for a greater V_{IFT}, making the $30-15_{IFT}$ an ideal field test to assess the entire locomotor profile in a single assessment.

Table 2: Balance of remaining *W'* (W'_{BAL}) expressed in absolute (kJ) and relative (%) terms for all four player profiles at the end of the 30-15 Intermittent Fitness Test.

	30-15 Intermittent Fitness Test			
	End-Stage Velocity (km/h)	Tlim (s)	*W´*BAL (kJ)	*W´*BAL (% remaining)
Fit and Fast (Full backs)	20.5	1155	0.02	-1.5
Fit and Slow (Midfield)	20.0	1110	-1.00	-3.6
Less Fit and Fast (Central defenders, Attackers)	19.0	1044	-0.98	-2.3
Less Fit and Slow	18.5	1005	0.96	3.0

Tlim = limit of tolerance in seconds (s); W'_{BAL} = balance of remaining *W'* (finite work capacity (kJ) above critical power).

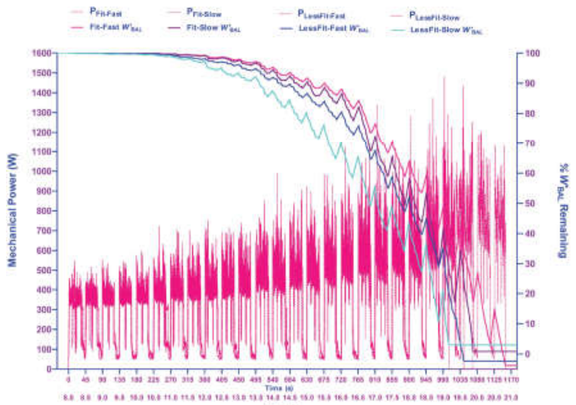


Fig. 6: Modelled expenditure and reconstitution of the balance of remaining *W'* (W'_{BAL}) during the $30-15_{IFT}$ in 4 players with clearly different locomotor profiles: 1) Fit and Fast; 2) Fit and Slow; 3) Less Fit and Fast; 4) Less Fit and Slow (Table 1).

Why choose the $30\text{-}15_{IFT}$: Insights for training prescriptions. It is worth mentioning that the MAS obtained with the UM-TT will remain the gold standard to prescribe linear (no CODs) and more continuous types of efforts ranging from prolonged submaximal (e.g., >15-20 min at 80% MAS) to HIIT with long intervals (e.g., 3-4 min 90-95% of MAS) intensities. When prescribing HIIT with short intervals, however, only the V_{IFT} can be used accurately for training prescription. As mentioned earlier, the speed reached at the end of the UM-TT doesn't account for the ASR and recovery abilities. And in contrast to common belief also, $V_{Yo-YoIR1}$ cannot be directly used for training prescription since its relationship with MAS is speed-dependent (Figure 7). When running at $V_{Yo-YoIR1}$, slow and unfit athletes use a large proportion of their ASR, while fitter athletes even run below their MAS!

The consequence of its ideal relation to both MAS (Figure 7) and athletes' overall locomotor profile (section 7) is that using V_{IFT} to program HIIT allows for better standardization of metabolic load in athletes presenting with different aerobic or anaerobic profiles. More precisely, in the initial study back in

2008 (Buchheit, 2008), using V_{UM-TT} as the reference running speed to calculate individual running distances during intermittent efforts induced very large between-player disparities in both exercise tolerance (1 of the 3 player couldn't even finish the sessions) and relative cardiovascular demands between athletes (CV >10% in HR responses). In contrast, when using V_{IFT} as the reference speed, all players could complete the session, and the relative cardiovascular responses were very similar with a CV <3%. In short, V_{IFT} was shown to be more accurate and suitable than MAS (determined using the UM-TT) for the individualization of HIIT with short intervals (Figure 8) (Buchheit, 2008).

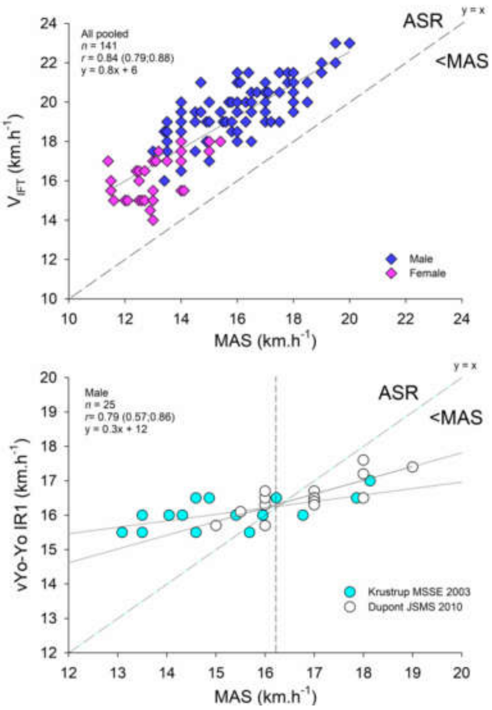


Fig. 7: Relationships between the speed reached at the end of the 30-15 intermittent fitness test (V_{IFT}, upper panel, redrawn from), the Yo-Yo intermittent recovery level 1 test ($V_{Yo-YoIR1}$, lower panel) and MAS. MAS data are directly taken from Dupont et al. (their Figure 1) (Dupont, Defontaine, Bosquet, Blondel, Moalla, & Berthoin, 2010); those from the study by Krustrup et al. are extrapolated from VO_{2max} values (their Figure 3) using a constant energetic cost of running (0.24 $ml.kg^{-1}.m^{-1}$ for footballers) (Krustrup, Mohr, Amstrup, Rysgaard, Johansen, Steensberg, et al. 2003) and assumes that MAS is 10-15% greater than vVO_{2max} (Berthon, & Fellmann, 2002).

To conclude, due to all the above-mentioned reasons, the $30-15_{IFT}$ is the only field test that allows a comprehensive evaluation of intermittent sports athletes' physiological capacities (including VO_{2max}, COD and inter-effort recovery abilities, and the ASR), that can be at the same time used for training prescription. Spreadsheets to automatize HIIT prescription are available here.

Why choose the 30-15$_{IFT}$ over the locomotor profile (i.e., MAS + MSS combo). Given the increased popularity of the ASR to both profile athletes and prescribe training (Sandford, Laursen & Buchheit, 2021), a new question has emerged; whether or not it would be better to directly use the locomotor profile (i.e. MAS and MSS), and in turn ditch the $30-15_{IFT}$ altogether. The response to this question is multifactorial:

- **Testing.** In elite team sports, and even more in football (soccer), testing is never easy - for different logistical, technical and cultural reasons.
  - Many people don't test directly for MSS. In this case, using the ASR approach is simply impossible - while logistically, implementing the $30-15_{IFT}$ is probably easier, safer and doesn't carry the same level of anxiety with regard to injury risk.
  - Another fact is that in many team sports, there is such an emphasis on effort specificity, such that performing a continuous protocol (as with a typical MAS test) has a very poor buy-in from both coaches and athletes. This makes the MAS test difficult to implement in the real world (coach unlikely to allow the test to be conducted), and/or the results very questionable (players unlikely to give a maximal effort). In contrast, the $30-15_{IFT}$ is perceived as specific and is consistently rated as less painful/more appropriate than a continuous test (Buchheit, 2005).
- **Profiling athletes.** It is true that the profiling information that brings both MAS and MSS together (and the ASR) is ideal in theory; based on the relative values of their MAS and MSS, athletes can be categorized as having an endurance-, hybrid- or speed-oriented profile (Sandford, Laursen & Buchheit, 2021). Since V_{IFT} is already a reflection of these two speeds (and the ASR) and CODs and recovery abilities (Buchheit, 2008), players' profiles are more difficult to highlight explicitly with the $30-15_{IFT}$.
  - However, in most team sports today, and especially at the elite level, only the speed- and hybrid-profile can tangibly impact the game and therefore, tend to represent the large majority of players to be tested (Haugen et al., 2012,; Slimani et al., 2019). Therefore, the need to profile is likely less important for this population in comparison with track and field athletes for example.
  - Moreover, the decision on whether a player may need to further develop his MSS vs. his MAS can probably be suggested from training and match observations (e.g. does the player manage to outsprint the opponent and win the ball? Does the player struggle to maintain game intensity over the length of a match? etc.). Finding the best reference speed to program HIIT, in contrast, requires taking all those factors into consideration simultaneously. This is where the trade-off comes into play!!
  - Finally, and especially at the elite level, the potential profiling information (if any) provided by using MAS and MSS may not always translate into improved training orientation and contents, i.e. there is generally little room to develop a given quality over another, since emphasis is on preparing for matches and recovery.
- **Training prescription.** If profiling is not the #1 reason, then prescription becomes the priority.
  - Modelled data from Figure 6 show how closely V_{IFT} is related to both the locomotor and energetic profiles. Recently, Vassallo et al. (2020) compared the accuracy of actual vs. predicted performance during the $30-15_{IFT}$ by modelling the balance of remaining finite work capacity (W'_{BAL}) derived from athletes' individual energetic

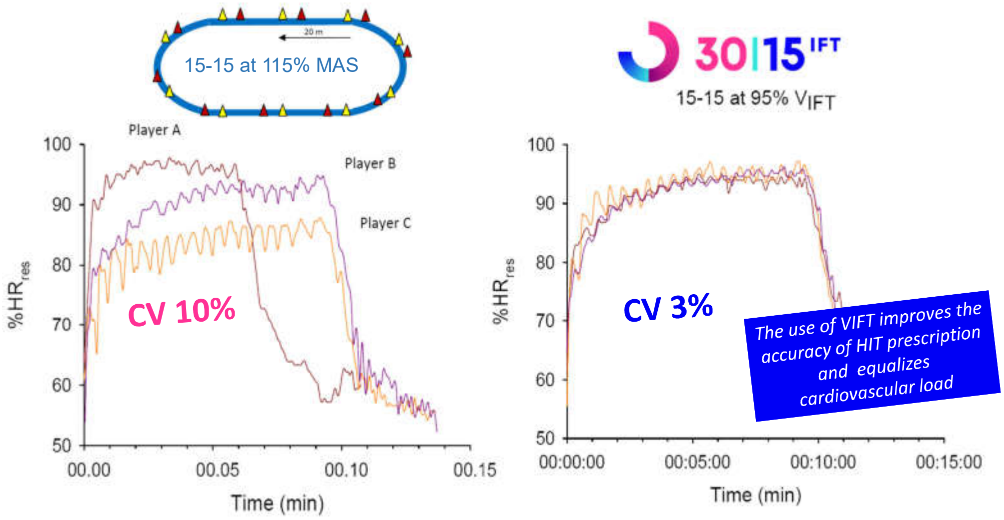


Fig. 8: Heart rate responses (HR, expressed as a percentage of HR reserve). Left panel: HIIT session with short intervals in the form of 9 x 15 s (run at 115 % MAS) interspersed with 15 s (passive recovery); Right panel: HIIT session with short intervals in the form of 9 x 15 s (run at 95 % V_{IFT}) interspersed with 15 s (passive recovery). Note that since V_{IFT} is 15-20% greater than MAS, different percentages of the reference speed we used.

profiles. There were strong correlations (r = 0.88) between actual vs predicted performance, with a mean difference of 1 stage (30 s). It remains to be seen whether prescription with ASR possesses a similar level of energetic sensitivity, specifically, on the cascade of internal physiological responses (*W'*) to mechanical work done.

- From a strict team-sport programming point-of view, there is yet little evidence showing the advantage of using the ASR over V_{IFT}. Ursula et al. (2019) also examined physiological, performance and perceptual responses to various HIIT sessions using different proportions of the ASR vs. % of MAS (Ursula, Valéria, Ana, Elaine, Fábio, & Emerson, 2019). Their results showed that in comparison to % of MAS, the use of proportions of the ASR (and therefore likely V_{IFT}) to program HIIT could reduce inter-subject variability by about 50% for both time to exhaustion and blood lactate responses. It is however worth noting that the CVs reported by Ursula et al. (2019) for time to exhaustion and blood lactate were still between 20 and 30%... so even though there was clearly 'less variability' than when using %MAS, those were still high CV% ... especially if we compare them to the HR reserve responses with CV <5% when using V_{IFT} as the reference velocity (Buchheit, 2008).
- In contrast, in the only study to date where ASR and V_{IFT} prescription was directly compared (Collison et al., 2021), the authors reported reductions in supramaximal interval running performance (15/15 HIIT format, no CODs) variability when prescribed by ASR - but not when prescribed by V_{IFT}. While not questioning the quality of the work of these authors, reducing HIIT responses to time to exhaustion only is likely a bit reductionist, since internal responses (e.g., time spent >90% HR/VO_{2max}, anaerobic contribution) - and their variability - may actually drive further the intended metabolic adaptations (Impellizzeri et al., 2019). Importantly also, it still remains to be examined whether using V_{IFT} may be more appropriate/similar/less appropriate than the ASR to reduce the variability of performance responses to HIIT between athletes. In fact, in Table 1 of their paper, Collison et al. (2021) reported very similar SDs for total time to exhaustion with all methods (and converted into CVs, it's 16% for all 3 methods!!), which appears at odds with their general conclusions.
- Crucially, COD ability is also a fundamental skill/capacity that is not accounted for using the typical ASR approach; V_{IFT} should in theory possess superiority in predicting supramaximal HIIT tolerance of drills performed with CODs. It is therefore difficult to think that this may not have impacted the results of Collison et al. (2021) if they had their athletes performing HIIT with CODs (i.e. increased mechanical work). Overall, we need more research here!

To conclude, while the $30-15_{IFT}$ may not provide the same level of objective information as compared to the MAS + MSS combo when it comes to profiling players (e.g., endurance vs speed-oriented profile), 1) the lower need for profiling in team sports, 2) somewhat easier implementation (no need to test for max speed and MAS separately, which likely results in greater coach and player buy-in) and 3) it's likely similar ability to predict HIIT tolerance (and therefore program HIIT) make the $30-15_{IFT}$ a more complete and versatile tool overall.

For practitioners willing to get the most out of all those testing options and obtain a complete set of tools, of course, the MAS + MSS locomotor profiling can be added - in a second time - (rather than substituted) to the 30-15_{IFT}. But in this case, to avoid running two incremental tests and gain better buy-in, it is suggested to estimate MAS using a 5 to 6-min or a 1.5 to 2-km time trial (Buchheit & Laursen, 2018). This practice has actually been well developed in AFL for a decade, where many teams systematically test MSS, V_{IFT} and run a 2-km time trial (e.g. Bellenger et al., 2015; Buchheit et al., 2015; Collison et al., 2021).

Methodological considerations to track changes in fitness and supramaximal intermittent running performance. *Interpreting changes in measures*
To assess the value of any individual change in V_{IFT}, prac-

titioners need to compare the measured change with the so-called smallest practical or meaningful change (SWC), while considering the possible noise around the measure (TE). To do so, practitioners may plot their data to see the latter variables in relation to each other (Figure 9), or for more precision, use a specifically designed spreadsheet that provides probabilities for the changes to be true (Hopkins, 2000).

For individuals, changes are generally considered as substantial when the probabilities are ≥75%, which occurs when the change is clearly greater than the SWC, and when the TE (plotted as positive and negative error bars) does not overlap with the SWC (Figure 9). Following these guidelines, the usefulness of a test measure can be assessed by comparing its associated noise (typical error of measurement, TE) and the SWC. A test can be considered as 'useful' when the noise is at least equal to or lower than the SWC (Hopkins, 2004). When, as often, the noise is larger than the SWC, the test can only assess moderate (i.e., 3 x SWC) to large (i.e., 6 x SWC) changes when using one repetition. As explained in details elsewhere (Haugen & Buchheit, 2015), repeating measures can allow decreasing the noise (by a factor of n repetition (Taylor et al., 2010)) and in turn, capture small changes. But while this is feasible with jump or sprint tests for example within seconds or minutes, repeating maximally the 30-15$_{IFT}$ the same day or even over a few days is almost impossible for physiological and logistical reasons. Therefore, since there is no real way to go around a possible reliability limitation while repeating the test, sticking to the actual TE value may matter even more than for other physical tests.

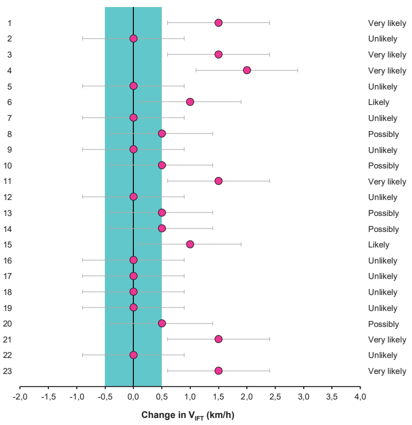


Fig. 9: Decision-making mechanism when interpreting changes using SWC and TE (Scott, 2018). The values for the SWC (0.5 km/h) and the error bars (2 TE, which is a pretty conservative approach) were chosen by the authors of the original publication.

Determining the SCW

The first and more objective approach to determine the SWC consists in using 0.2 of the between-athlete standard deviation (SD) of the team or group of athletes of interest (Hopkins, 2009). However, since using the group SD to estimate the SWC is directly affected by group homogeneity, we decided to average the SDs of hundreds teams tested (Laursen & Buchheit, 2018, Figure 10), which provides a pretty robust, less sample specific-dependent SD on which the SWC can be based. Our results on both female and male athletes suggested the average SD of V_{IFT} to be 1.3 ± 0.4 km/h, irrespective of the sex and performance level. As shown in Table 3, the different fractions of this SD allow to mechanically determine small (0.2 SD), moderate (0.6 SD) and large (1.2 SD) changes.

Table 3: Average standard deviation (SD) of the V_{IFT} SD of hundreds teams tested (Figure 10, Laursen & Buchheit, 2018), and the typically-derived smallest worthwhile change (SWC, using 0.2 of the average SD). Magnitude for moderate (MWC, 0.6) and large (LWC, 1.2) changes are also provided. Note that since there were differences between sex and performance levels, all data were pooled together to increase sample size.

Fraction of the V_{IFT} average SD	km/h	%
1	1.3 ± 0.4	7 ± 2.5
SWC (0.2)	0.3	1.4
MWC (0.6)	0.8	4.2
LWS (1.2)	1.6	8.4

The other, and more pragmatic way to determine the SWC is to use performance clues, or any data derived from the field that make sense to practitioners (Haugen & Buchheit, 2015). Since there is no correlation between a player's fitness and neither match running activity and overall match performance (Mendez-Villanueva & Buchheit, 2011), it's difficult to suggest what magnitude of change in V_{IFT} can be considered as meaningful in terms of team sport performance. The approach that we suggest here is therefore based on training aspects: when implementing HIIT, most conditioning coaches tend to group their players based on their V_{IFT} , using 1-km/h intervals, e.g., 18, 19, 20, 21 km/h. Therefore, to change groups, athletes need to improve their V_{IFT} by 1 km/h (2 stages) - this magnitude of change can consequently be considered as the SWC. Note that this 1-km magnitude change is consistent with a moderate change, when assessed statistically (Table 3).

Reliability

The reliability of the 30-15$_{IFT}$ has been examined by several studies, summarized in Table 4. Analyses of relative reliability using correlation coefficients and/or intra-class correlation coefficient (ICC) have reported values ranging from 0.85 to 0.96, which are very similar to those reported for the Yo-Yo tests for example, i.e., 0.78 to 0.98 (Grgic, Lazinica, & Pedisic, 2020).

While these measures are important when it comes to comparing individuals, it is the TE, a measure of absolute reliability, often expressed as a coefficient of variation (CV) (Hopkins, 2000), that, as explained above, provides the more relevant information for a monitoring purpose. The average TE reported in the different studies was shown to be 0.5 km/h, which corresponds to one stage increment (Table 4).

To summarize, an important/meaningful change in V_{IFT} lies probably between 1 and 2 stages, depending on the approaches taken – 1 km/h being considered statistically as a moderate change (Table 3). If we are now to add the TE to the change to allow a clear and certain change, the minimum change to be observed to ascertain a meaningful and real change would therefore need to stand between 1 and 1.5 km/h.

Sensitivity to training

The sensitivity of the $30-15_{IFT}$ to training was assessed and compared with that of the Yo-YoIR1 in fourteen young soccer players, who performed both tests before and after an eight-week training intervention (two weekly HIIT sessions after technical training) (Buchheit, & Rabbani, 2014). While within-test % changes suggested a greater sensitivity to training for the Yo-YoIR1 (+35%) compared with the $30-15_{IFT}$

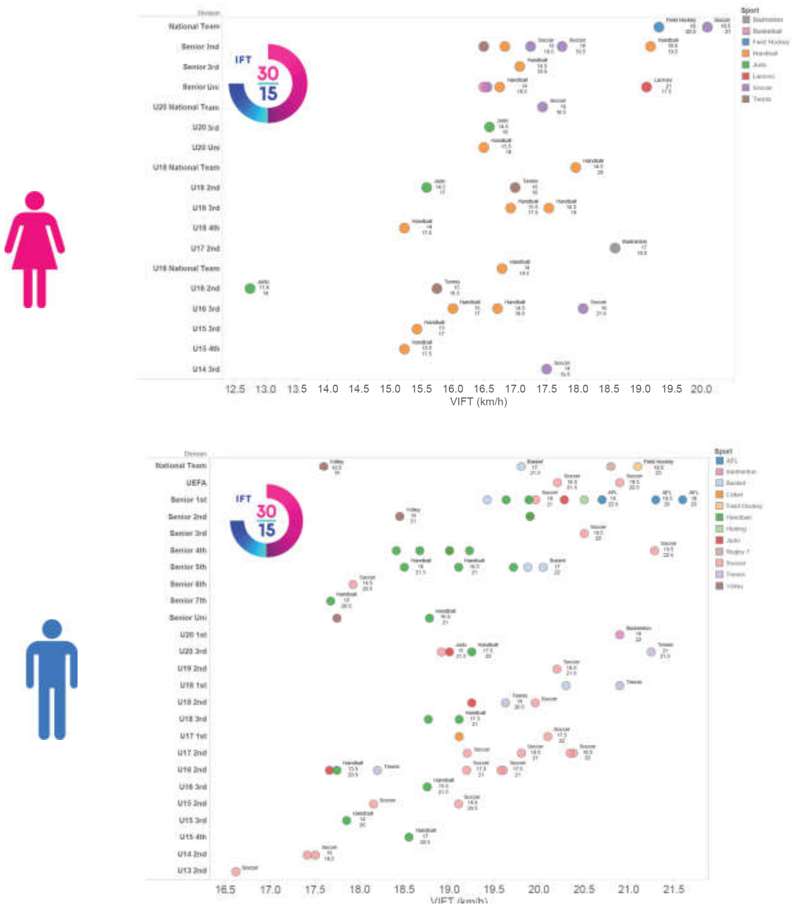


Fig. 10: Selected V_{IFT} performance for female (upper panel) and male (lower panel) as a function of sports, age and playing standard. (Laursen & Buchheit, 2018).

(+7%) (Figure 11A), these changes appeared very similar when 1) they were considered with respect to the SWC each test and 2) standardized in relation to group SD (i.e., expressed as an effect size, ES): +1.2 and +1.1 for the Yo-YoIR1 and V_{IFT}, respectively (Figure 11B). Similarly, the difference in the changes between the two tests fell within the SWC, whatever the unit (%, Figure 11C or ES, Figure 11D).

Table 4: Reliability of the $30-15_{IFT}$

	Buchheit, M. et al. (2011)*		Ković, N. et al. (2016)*			Jeličić, M. et al. (2019)*			Scott, T.J. et al. (2015)**		Thomas, C. et al. (2016)	Valladares-Rodríguez, S. et al. (2017)*[a]		Mean Values		
	V_{IFT}	HRpeak	V_{IFT}	HRpeak	VO_{2max}	V_{IFT}	HRmax	VO_{2max}	V_{IFT}	HRpeak	V_{IFT}	V_{IFT}	HRpeak	V_{IFT}	HRpeak	VO_{2max}
Inter-class correlation coefficient (ICC)-90% or 95% CI	.96 (CI=.91; .98)	.97 (CI=.91; .99)	0.91 (CI=.80- .96)	.94 (CI=.85- .97)	.94 (CI=.87- .98)	.85 (CI=.66- .93)	.96 (CI=.81- .98)	.85 (CI=.66; .93)	.89 (CI=.81- .93)	.96 (CI=.89- .99)	.80 (CI=.65- .91)	.92 (CI=.82- .97)	.90 (CI=.63- .98)	.88	.94	.89
Coefficient of variation (CV%) 90% or 95%	1.6% (CI=1.3–2.3)	.7 % (CI=.5–1.1)	1.8 (CI= 1.4; 2.7)	1.2 % (CI=.9-1.7)	1.6 (CI=1.2- 2.3)	5.99 % (CI= 4.76- 8.21)	4.83 (CI= 3.83-6.62)	4.90 (CI=3.89- 6.72)	1.9%(CI=1.6 -2.4)	.6% (CI=.5- 1.0)	2.5% (CI=1.9-3.8)	1.5% (CI=1.2- 2.3)	1.4% (CI=1.0-2.7)	2.54	1.74	3.25
Typical error of measurement (TE) 90% or 95%	.29 km/h (CI=.23-.41)	1 b/min(CI=1–2)	.31 (CI=.24- .45) km/h	2.0 (1.73; 3.21) b/min	.71 (CI=.55- 1.02)	.56 km/h (CI=.44- .77)	2.15 (CI=1.70; 2.98)	1.16 (CI=0.91- 1.60)	.36 (CI=.30- .44)	1 b/min (CI=.89- 2.05)	1.0 km/h (CI=1.02- 1.04)	.32 km/h (CI=.24; .47)	<1 $b.min^{-1}$ (CI=1-3)	.47	< 1.43	.93
Smallest worthwhile change (SWC)	.31 km/h	0.7%	.20 km/h	0.7%	.55 (1.2%)	.20 km/h	0,01	.42	.21 km/h	0.5%	.70 km/h	.34 km/h	0.8%	.32 km/h	0.74%	.48
TE + SWC	.60 km/h	2 b/min	.51 km/h	4 b/min	1.26	0.76 km/h	4.04 b/min	1.58	.57 km/h	2 b/min	1.7 km/h	.66 km/h	< 2 b/min	.8	< 2.80	1.42

*: 90 % CI
**:95 % CI
a: data were obtained for a subsample of the male.

Typical changes in fitness and supramaximal intermittent running performance as assessed via the 30-15$_{\text{IFT}}$. Figure 12 presents an overview of the changes in V_{IFT} reported in 22 different studies (30 sub-groups in total) following HIIT supplementation, as a function of training duration and number of sessions. Those data add to the recent analysis presented by Bok and Foster (2021), where training-induced changes in V_{IFT} were reported for 10 studies. The average change reported (at the group level) is about 1 km/h, which is within the range of the minimal meaningful changes examined in section 9. Interestingly, there doesn't seem to be an effect of session number and/or training duration, confirming that the minimum effective dose of HIIT supplementation can be pretty short (2-4 weeks), and that training for longer periods doesn't always bring larger benefits (MacInnis & Gibala, 2017).

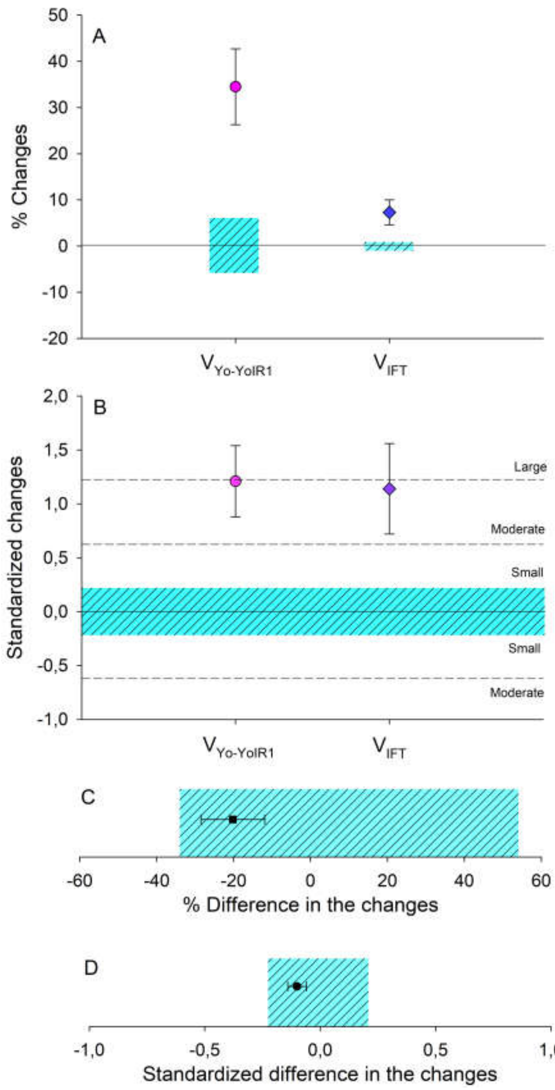


Fig. 11: Training-induced changes (90% confidence intervals) in performance for the Yo-Yo Intermittent Recovery Test Level 1 ($V_{Yo-YoIR1}$) and the 30-15 Intermittent Fitness Test (V_{IFT}) as expressed in percentage (panel A) or as standardized changes (panel B). Differences in the changes (90% confidence intervals) are expressed as % (panel C) or standardized differences (panel D). Shaded areas represent SD-related (0.2) ranges of trivial change/difference (Buchheit, & Rabbani, 2014).

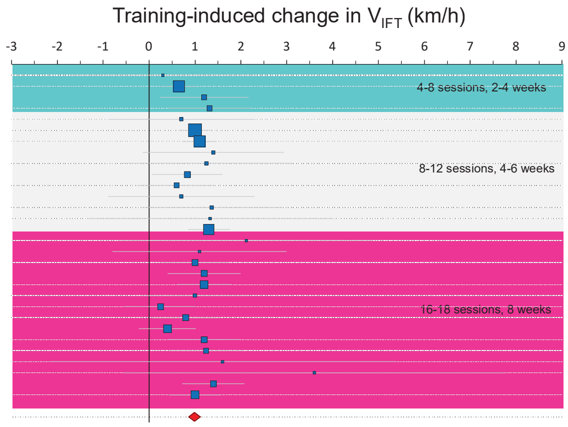


Fig. 12: Training-induced changes (90% confidence intervals) in performance for the 30-15 Intermittent Fitness Test (V_{IFT}) as a function of study duration and number of sessions.The size of the squares is related to each study sample size. Data were extracted from Arazi, Keihaniyan, Eatemady-Boroujeni, Oftade, Takhsha & Asadi, 2017; Buchheit, Millet, Parisy, Pourchez, Laursen, & Ahmaidi, 2008; Buchheit, Laursen, Kuhnle, Ruch, Renaud, & Ahmaidi, 2009; Buchheit, Mendez-Villanueva, Quod, Quesnel, & Ahmaidi, 2010; Buchheit, & Rabbani, 2014; Buchheit, Rabbani, & Beigi, 2014; Barreira, & Almeida, 2020; Campos-Vazquez, Toscana-Bendala, Mora-Ferrera, & Suarez-Arrones, 2017; Dellal, Varliette, Owen, Chirico, & Pialoux, 2012; Delextrat, Gruet, & Bieuzen, 2018; Fernandez-Fernandez, Sanz-Rivas, Sarabia, & Moya, 2015; Fernandez-Fernandez, Sanz, Sarabia, & Moya, 2017; Harrison, Kinugasa, Gill, & Kilding, 2015; Kelly, 2015; Lapointe, Paradis-Deschênes, Woorons, & Lemaître, 2020; Paul, Marques, & Nassis, 2019; Philp, Buchheit, Kitic, Minson, & Fell, 2017; Rabbani, Clemente, Kargarfard, & Jahangiri, 2019; Rabbani, Kargarfard, Castagna, Clemente, & Twist, 2019; Seitz, Rivière, De Villarreal, & Haff, 2014; Viaño-Santasmarinas, Rey, Carballeira, & Padrón-Cabo, 2018.

Conclusion

More than 20 years of international research and worldwide application of the $30-15_{IFT}$ have clearly improved our understanding of the test benefits in terms of athlete evaluation and HIIT prescription.

The final speed reached at the end of the test, V_{IFT}, is directly related to athletes' overall locomotor and metabolic profile (including their MAS, MSS and in turn, their ASR), and taxes all physical capacities required when performing HIIT. For these reasons, V_{IFT} has no equivalent when it comes to prescribing HIIT (especially with short intervals); using V_{IFT} allows homogenous, individualized metabolic and perceptive responses to HIIT.

The advanced knowledge about its locomotor and metabolic determinants has also provided key information to optimize its implementation within sessions (as a specific sequence in between other technically/tactically-oriented sequences) and during the pre-season (it can be implemented as early as within the first 2 weeks).

Finally, the accumulation of data in relation to the test reliability, together with the numerous reports of training-induced V_{IFT} changes have also helped us to 1) confirm the great sensitivity of the test, and 2) determine the minimum change in V_{IFT} to be considered meaningful at the individual level (i.e., 1 to 1.5 km/h).

Training studies using the $30-15_{IFT}$ to evaluate the effect of HIIT supplementation have also suggested that improvements of 1 to 1.5 km/h should be expected, with no additional benefits of interventions >1 month.

Practical applications

- The $30-15_{IFT}$ is the only field test that can be used to both assess athletes' high-intensity intermittent performance AND programming HIIT with short intervals.
- Since the performance during the test is a strong reflection of both the locomotor and metabolic profiles of an athlete, using V_{IFT} as a reference speed for run-based HIIT prescription allows for a tight individualization of metabolic and perceptive load when performing HIIT with short intervals.
- More research is still needed to understand the benefit of prescribing HIIT using V_{IFT} vs. the entire locomotor profile (i.e., MAS, MSS and the ASR). In theory, results should be quite similar given the fact that MAS and MSS together accurately predict V_{IFT} - and since V_{IFT} also integrates COD ability, it could even possess superiority to the MAS + MSS combo. Practical considerations and the ability to test MSS and/or use a linear and continuous MAS test may pose more decisive factors in this regard, with the decision left to practitioners within their own context.
- When it comes to programming the $30-15_{IFT}$ within a typical training session of the weekly microcycle, its (both internal and external) load can replace that of a specific technical/tactical sequence. This suggests that it can be programmed as early as during the 1^{st} or 2^{nd} week of preseason.
- Changes between 1 and 1.5 km/h can be considered as meaningful at the individual level.
- HIIT supplementation can lead to 1 to 1.5 km/h improvements in V_{IFT}, with no greater benefit of training periods longer than 2-4 weeks (4-8 sessions).

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