Review article

The 30-15 Intermittent Fitness Test : 10 year review

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Happy birthday, to the 30-15 Intermittent Fitness Test (30-15$_{IFT}$)! In July 2010, the test celebrates its 10th anniversary. How time flies! This enables me the opportunity to reflect on the past 10 years, seize the time to (re)clarify the interest and utility of the test, and at last to present the last researches that have been conducted on/or with the 30-15$_{IFT}$; all being aimed at improving both the evaluation of team/racket sport athletes and the scheduling of interval-training sessions. Finally, I thank all the test users for their helpful feedback, which have all motivated the writing of this review.

I. History.

I.1. The idea. Everything started during the summer of 1999. As a strength & conditioning (S&C) coach - and player - in a French Handball team in Strasbourg (performing at the 4th French level), I was at this present time using the 'Léger-Boucher' track test (also known as the University of Montreal track Test (29)) to evaluate cardiovascular fitness of our players. While using the final velocity (V_{L-B}) to individualize running distances during interval-training sessions (3, 24). For long intervals, that was fine. Each player having to cover a distance based on his own capacity, I still see us performing well at 85-90% of V_{L-B} for 10-12 or even 15 min. Nevertheless, a little bit later during the preparatory phase, when we started to work at higher intensities in the indoor field (i.e., shuttle-runs at intensity above V_{L-B}), things started to be different. Some players were struggling, while others were having an 'easy' time!? That surprised me, since I was still individualizing running distance based on each player's capacity (i.e., 120% of V_{L-B})! In fact, in the team, all players have different athletic and anthropometric profiles: some were tall, some were short, some were quick, some were slow, and there were some blacks, some whites…. I then started to realize that the players' responses to high-intensity intermittent exercise with changes of directions (COD) were clearly related to many factors other than those evaluated when using the 'Léger-Boucher' track test (e.g., COD ability, inter-effort recovery abilities, anaerobic capacity). I started to feel the need of a new field test, which could assess, in addition to maximal cardiorespiratory fitness, these additional factors. The idea of an intermittent incremental field test including COD, leading to higher maximal running speeds than the usual protocols, has just evolved.

I.2 The (good) protocol. It took me more than a year of readings, talks and trials to seal the actual 30-15$_{IFT}$ protocol (7). On different surface, at different venues, I have personally trialed more than 30 different versions of the test, based on different increments, stage duration, recovery periods, etc! For many reasons detailed later in this document, I came up with the following formula: repeated 40-m shuttle-runs during 30 s, interspersed with 15 s of active (walking) recovery, and a speed increment of 0.5 km/h per stage. The 30-15$_{IFT}$ was 'born' in July 2000. Just in time for the start of the physical preparation period ☺. Now it was time to prepare the audio track in order to trial the test with several teams around Strasbourg (e.g., handball talent centers, basketball, handball and football [soccer] clubs) before testing 'officially' the Young Women's French National handball Team 85-86 in July 2002, and the SC Selestat Handball (1st league) in August 2003. The 'scientific' validation came only later, with the first draft of the manuscript now published in the ''*The Journal of Strength & Conditioning Research''* (JSCR) (7) finished in December 2004. The definitive version of the paper was finally accepted early in 2007, and published in December 2008! (hurrah for the publication delays). In the mean time, to save time, numerous data has been sent for publication in the French handball coaching journal, the *''Approches du hand''* in 2005 (11, 12, 14).

I.3. Review of the test use. Today, handball teams in France are the prime users (all categories, levels, males and females). Nevertheless, as early as 2003, its wide use and acceptance as a popular test has evolved more and more in many other sports, including basketball (Strasbourg Pro A, Federal center in the INSEP, Men French National Team in 2006), football (Lille, National Centre in Clairefontaine and many other clubs in all divisions), rugby (Top 14), badminton (INSEP), tennis (INSEP, exteam Lagardère), judo (French training center in Strasbourg), futsal… In other countries, many teams at the highest levels are also using the test today such as in football (UK, Italy, Germany, Belgium, Qatar, Canada, USA, Australia), basketball (USA, Thailand), handball (Germany, Belgium, Greece, Tunisia, Qatar, Croatia, Romania, Poland), rugby (Australia, UK, Ireland), AFL (Australia), netball (Australia, Nouvelle Zeeland), Field Hockey (England National teams, men and women). The above mentioned sports/teams are only those whom I have been recently in contact with, please forgive me if I have missed someone as the list is possibly quite large now. In parallel, the use of the test has also become more popular within schools (13) because of its intermittent nature, which makes the test more 'physiologically appropriate' for children and adolescents (34) and less painful for the untrained population. Finally, the test is also presented in several S&C courses in France and around the world, and is cited on several web pages, which is likely reflecting the interest that practitioners have for the 30-15_{IFT} ☺.

II. Field tests aimed at evaluating cardiorespirtory function

II.1. Final velocity (or end-test velocity), maximal aerobic velocity and vVO_2max. For any continuous test (including no recovery period) as Léger's tests (with shuttles (30) or not (29)) and its variants (e.g., Vam-Eval (23)), it is worth differentiating the final velocity reached from what is (should be) called the 'maximal aerobic velocity' (MAV). While these two terms are often used interchangeably, they refer to different physiological entities. As illustrated on Figure 1, during an incremental test, maximal oxygen uptake (VO_2max) is often reached BEFORE the end of the test. The MAV, or vVO_2max to be more explicit, is actually not the end-test velocity, but the lowest running velocity that elicited VO_2max (4). In this example (Figure 1), the final velocity at the Léger-Boucher track test (V_{L-B}) = 18 km/h, but vVO_2max = 16.5 km/h ! After the attainment of VO_2max (16.5 km/h), the player has used some anaerobic sources to finish the last stage. Therefore, while vVO_2max is a true and valid index of maximal aerobic function, the end-test velocity can be considered as a composite velocity, since not exclusively related to VO_2max. While both velocities are highly correlated, the difference between final velocity vVO_2max is not constant, and depends on how much the athlete did push to finish the test (using therefore more his anaerobic resources; on several occasions I have observed highly motivated athletes presenting a difference as extreme as 3 km/h). Since vVO_2max can only be determined with the use of gaz analyzers (in the lab on a treadmill or on the track with a portable device), most practitioners have to do their best with the final velocities measured on the track. Some coaches remove therefore 1-1.5 km/h to the final velocity to approach vVO_2max; others keep the final speed but use slightly different (i.e., slightly lower) percentages when programming interval training sessions.

II.2. All velocities derived from lab and field tests are protocol-dependent. In fact, while they are all well correlated, the end-test velocities (and vVO_2max) obtained via different incremental (field) tests differ all from each other. As exemplified in Figure 1, the energetic cost of running is much greater with COD, so that the slope of the VO_2/velocity relationship is much steeper. Therefore, for a given VO_2max (i.e., end-point), both vVO_2max and the final velocity reached are substantially lower during a shuttle test (1). In the same line, a test with longer stage durations is likely to lead to lower final running velocity because of premature muscle fatigue. Therefore, to avoid any confusions, it is preferred to name the final running velocity observed for a given test as «$V_{+name\ of\ the\ test}$ », and eventually «$v_{+name\ of\ the\ test}VO_2max$ » for vVO_2max.

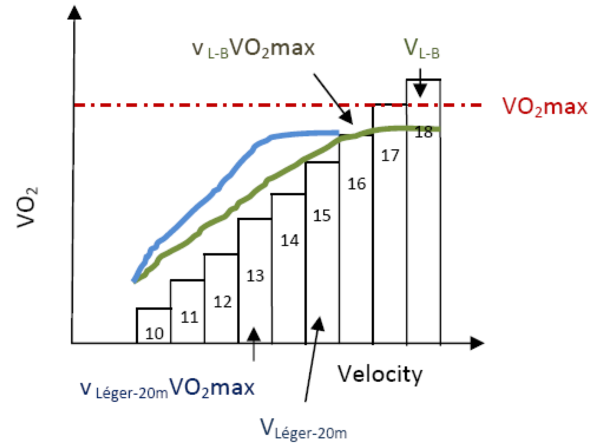

Figure 1. Time course of VO_2 during an incremental shuttle (blue) or straight-line (green) test. The energetic cost of running being greater during the shuttle test because of the COD, the velocity reached at VO_2max (vVO_2max) and therefore the final velocity are substantially lower than these during the straight-line test. In the same line, a player with a poor running economy is also likely to reach lower running speeds than a more economical player with a similar VO_2max, and conversely.

II.3. Terminology. Another important point concerns the use of the term 'maximal aerobic velocity' (23). To me, this term should only be used to qualify velocities measured during continuous straight-line tests, such as Léger-Boucher or Vam-Eval tests. Indeed, the vVO_2max reached during the 20-m shuttle run test is so far from that reached during a straight-line test (Figure 1), and so dependent on COD ability, that using the term MAV for this test is definitively misleading. Moreover, the shortening of shuttle length is likely to additionally lower the running velocities (5). Similarly, the nature/duration of the efforts and/or recovery periods during intermittent tests such as the 30-15_{IFT} or the Yo-Yo (2) influence substantially the velocities reached. Again, using MAV for these tests makes no sense, and the use of «$V_{+name\ of\ the\ test}$ » is the also best option. It is however important to consider the physiological capacities taxed during a given test to fully understand what its end-test velocity represents. As exemplified later in this document, this will justify the percentages of the end-test velocity used during training.

III. Acute responses to high-intensity intermittent shuttle-runs.

These types of effort are considered as "mixed", since they tax both the aerobic and the anaerobic (since the running intensity is above vVO_2max) systems at high levels. VO_2max is sustained for 30-70% of exercise time and blood lactate levels are generally quite high (i.e., >10-12 mmol/l) (3, 18, 25, 35). In addition, because of the supramaximal velocities used, and more particularly because of the repeated deceleration and acceleration phases related to the COD, such sessions are likely to put an important stress on the neuromuscular system (36). Finally, these responses are likely modulated by the individuals inter-effort recovery ability; an athlete presenting faster cardiovascular/metabolic/neuromuscular adjustments during the recovery period being more likely to experience less performance decrement over the repetitions (for review see (26)).

IV. Anaerobic Velocity Reserve (AVR) (22). While still poorly used by coaches today, the AVR is a primordial quality to evaluate and to take into account for training prescription. The AVR represents a 'reserve' of running velocity left to the player once he has reached his vVO_2max (i.e., the difference between maximal sprinting velocity and vVO_2max, Figure 2). Although in the literature the AVR is said to be exclusively limited by maximal running velocity (22), it is to me also substantially influenced by the anaerobic capacity (as an energy store), which will determine the time that a given percentage of the AVR can be sustained. Specifically, when dealing with two players, while player A, with a vVO_2max of 18 km/h and a maximal sprinting velocity of 29 km/h (measured as the best split time during a 40 to 50-m sprint), has an AVR of 29-18 = 11 km/h; a player B with a similar vVO_2max but a maximal sprinting velocity of 33 km/h has therefore a greater reserve to use from during high-intensity runs (AVR = 14 km/h). For a 15''-15'' exercise performed at 120% of vVO_2max (21.5 km/h) for example (25), despite a similar cardiorespiratory load (let's say that both players have similar COD and inter-effort recovery abilities), it is evident that the player A will work at a greater relative percentage of his AVR (33% vs. 24% !). Training load will therefore not be equivalent for both athletes. As demonstrated later in this document, the velocity reached at the end of the 30-15_{IFT} partly reflects, among other physiological qualities, a player's AVR. Its use as a reference velocity to program high-intensity intermittent runs, and not vVO2max or any velocity determined with a continuous test, guarantees that all players present similar aerobic and anaerobic load.

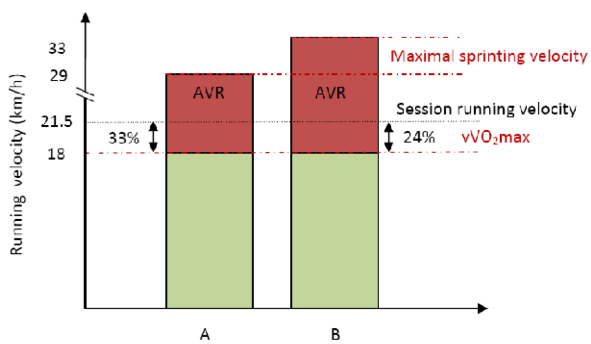

Figure 2. Schematic illustration of the Anaerobic Velocity Reserve (AVR) of two players having a similar vVO2max but different maximal sprinting speed. During a high-intensity interval-training session, player B having a greater AVR will work at a lower percentage of its AVR, and will therefore present a lower exercise load compared with player A.

V. The 30-15_{IFT} : protocol, reliability and validity.

V.1. Protocol. The 30-15_{IFT} consists of 30-s shuttle runs interspersed with 15-s passive recovery periods. Velocity is set at 8 $km.h^{-1}$ for the first 30-s run, and speed is increased by 0.5 km/h every 30-s stage thereafter (well-trained players can start the test at 10 or even 12 km/h to save time). Players are required to run back and forth between two lines set 40 m apart (Figure 3) at a pace, which is governed by a prerecorded beep. The prerecorded beep allows the players to adjust their running speed when they enter a 3-m zone placed in the middle and at each extremity of the field. During the 15-s recovery period, players walk in a forward direction towards the closest line (at either the middle or end of the running area, depending on where their previous run had stopped); this line is where they will start the next run stage from. Players are instructed to complete as many stages as possible, and the test ends when the players can no longer maintain the required running speed or when they are unable to reach a 3-m zone in time with the audio signal for three consecutive times. The velocity attained during the last completed stage, determined as the player's V_{IFT}. VO_2max can be estimated from the V_{IFT} according to the following formula: $VO_2max_{30\text{-}15IFT}$ ($ml.^{-1}min.kg^{-1}$) = 28.3 - 2.15 G - 0.741 A -0.0357 W + 0.0586 A x V_{IFT} + 1.03 V_{IFT}, where G stands for gender (female = 2 ; male = 1), A for age, and W for weight.

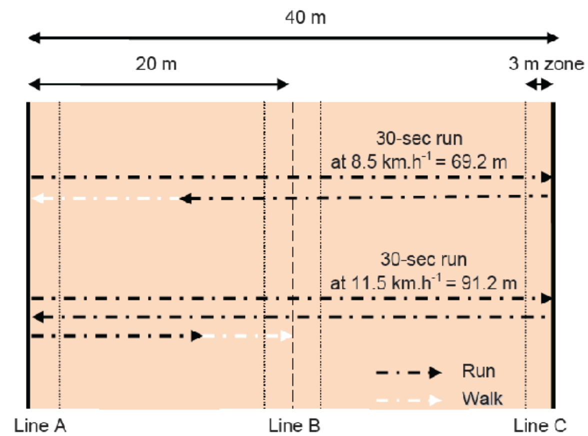

Figure 3. Area prepared for the 30-15_{IFT} and example of two intermittent runs. For the run at 8.5 $km.h^{-1}$ (about 69.2 m in 30 sec), subjects start at line A, run to line C crossing line B and then return. After crossing line B again, they stop after 8.5 m and walk to line A during the 15-sec recovery to be ready for the next stage. For the run at 11.5 $km.h^{-1}$ (about 91.2 m in 30 sec), subjects start at line A, make one complete round trip and stop after 9.5 m when going towards line B, then walk to line B during the 15 sec of recovery for the next start. Note that calculation of targeted distances take into account the time needed for the direction changes.

V.2. Reliability

Assessing the level of reliability of a test is primordial to ensure that collected data can be used to monitor a player's changes in fitness level during a season. From a test re-test conducted on 20 regional-to-national level handball players, we calculated the typical error of measurement to be of 0.3 km/h (95% CL, 0.26 to 0.46) (8), which suggests that a change of about 1 stage (i.e., 0.5 km/h) is already worthwhile. Indeed, the calculated smallest worthwhile changes being smaller than 1 stage, a change as small as 0.5 km/h in V_{IFT} can be considered as substantial.

V.3. Validity of the 30-15_{IFT}.

Construct validity. Since the first objective of the 30-15_{IFT} is to provide a reference running velocity for the scheduling of high-intensity interval-training session performed with COD, it was important to verify that:

- Reaching V_{IFT} elicits VO_2max (which implies that during training sessions, running close to V_{IFT} will enable players to work at or near VO_2max). This was confirmed while comparing maximal VO_2 values reached during the 30-15_{IFT} with these reached during a reference incremental test (i.e., Léger-Boucher track test (15)).
- V_{IFT} is much faster than vVO2max and the anaerobic contribution to the test is also much higher during the 30-15_{IFT} than during a continuous straight-line test (both implying a greater use of the AVR). This was verified since V_{IFT} is generally 2 to 5 km/h faster than vVO2max, and blood lactate levels were shown to be 40% greater after the 30-15_{IFT} than after the Léger Boucher track test (15).
- V_{IFT} is simultaneously related to maximal aerobic function, anaerobic capacity (or at least the proportion of AVR used), neuromuscular and COD qualities, inter-effort recovery abilities and repeated-sprint abilities; all these qualities being elicited while performing high-intensity shuttle intermittent runs. This was confirmed in 60 to 118 young handball players (Figure 4) (6, 7).

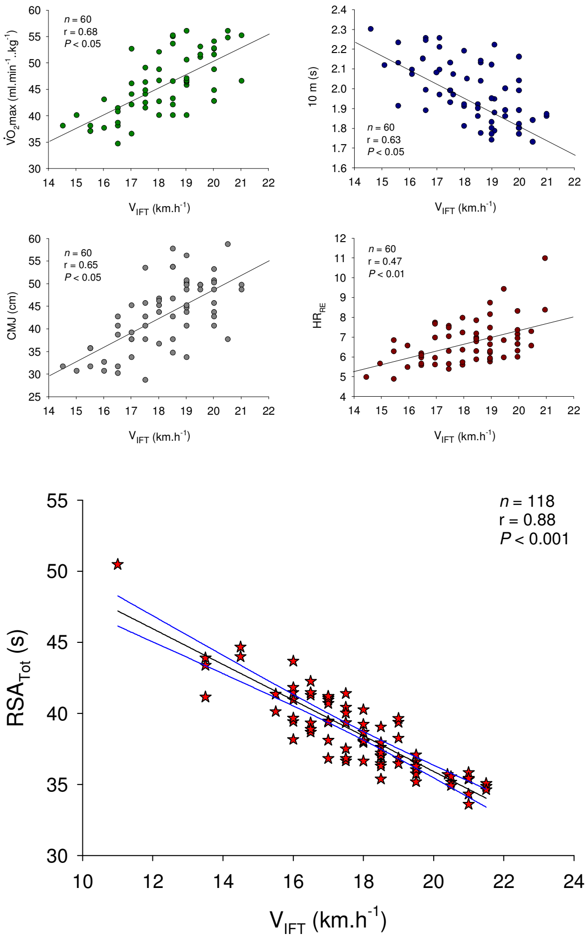

Figure 4. Relationships between V_{IFT} and VO_2max, neuromuscular qualities (10-m sprint time and jumping height [CMJ]), inter-efforts heart rate recovery (HR_{RE}) (7) and performance on a repeated-sprint test (RSA_{Tot} corresponding to the total sprint times (6 x [2x15-m shuttle-sprints]) (6). This illustrates well that V_{IFT} reflects all these capacities simultaneously.

- The correlation between V_{IFT} and other popular end-test velocities is not excellent, i.e., suggesting that the 30-15$_{IFT}$ is effectively measuring something else in addition to maximal cardiorespiratory function (such as anaerobic capacity, inter-efforts recovery and COD abilities). While $V_{L\text{-}B}$ is almost exclusively related to VO_2max (r = 0.96 (29)) and $V_{Léger\text{-}20m}$, to both VO_2max and COD abilities, V_{IFT} is simultaneously correlated to a number of physiological factors (see above). Therefore, if V_{IFT} is a valid composite measures of all the aforementioned physical qualities, it should not be perfectly correlated with either $V_{L\text{-}B}$ or $V_{Léger\text{-}20m}$. While larger relationships are nevertheless expected between V_{IFT} and $V_{Léger\text{-}20m}$ than betwen V_{IFT} vs. $V_{L\text{-}B}$ since V_{IFT} and $V_{Léger\text{-}20m}$ share more common factors (i.e., VO_2max + COD vs. VO_2max only for $V_{Léger\text{-}20m}$ and $V_{L\text{-}B}$, receptively), the correlations were reported to be quite similar (r = 0.80 vs. 0.79, Figure 5) (7, 14). This is likely related to the fact that the neuromuscular system does not only determine COD ability ($V_{Léger\text{-}20m}$), but also running economy at high running speed (and then the $V_{L\text{-}B}$ reached) (32). Nevertheless, this provides further support to the validity of 30-15$_{IFT}$: the neuromuscular system is highly solicited not only during the COD, but it is also highly solicited to support the fast running velocities during the last stages of the test.

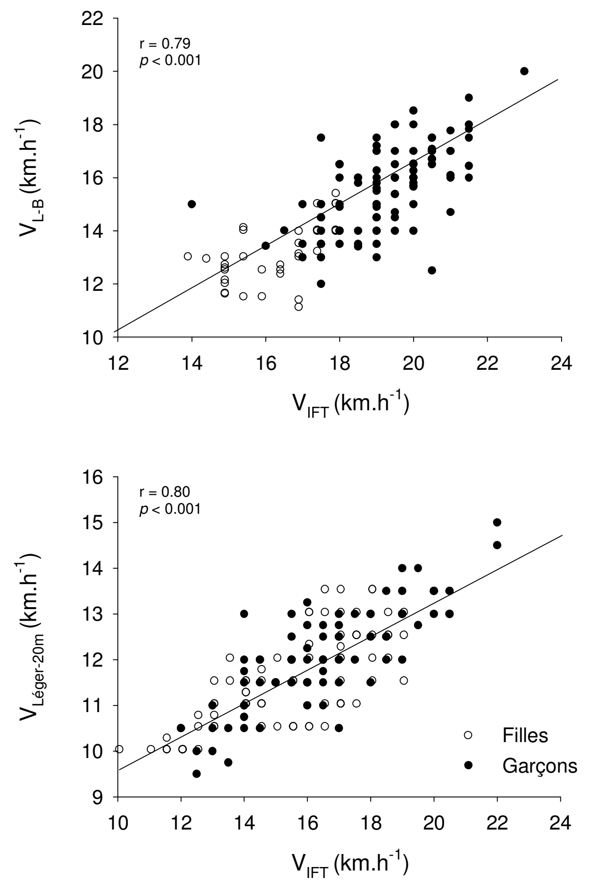

Figure 5. Relationships between V_{IFT} et $V_{L\text{-}B}$ et $V_{Léger\text{-}20m}$. The relationships are good but not perfect since V_{IFT} reflects more physiological capacities than the other velocities (14).

- V_{IFT} values reflect players' standard of play, i.e., the fitter players playing at the highest levels, the best teams should present the highest values. This was also confirmed, since as expected, male teams competing at the highest level display faster velocities; this again exemplifies the validity of the test (i.e., 'discriminative power' of the test) (Figure 11 at the end of the present document).

Conceptual validity. How does the V_{IFT} reflect, in addition to maximal cardiorespiratory function, the anaerobic capacity, neuromuscular qualities and inter-effort recovery abilities? The contribution of the anaerobic capacity and neuromuscular qualities to the V_{IFT} reached is indirectly related to both the magnitude and the percentage of the AVR used during the last stages of the 30-15$_{IFT}$ (especially for all stages run at a speed >vVO_2max, Figure 6, A-B). As demonstrated in Figure 1 where the shuttle runs are associated with a greater energetic cost of running and therefore a lower vVO_2max, players with poor COD abilities will have a poor running economy and will therefore reach lower vVO_2max, and proportionally lower V_{IFT} (Figure 6, C). Similarly, inter-effort recovery abilities affect the slope of the VO_2/velocity relationship and/or muscular fatigue development. When an inferior inter-effort recovery ability is present, a steeper slope is evident, muscle fatigue development is earlier, and, in turn, the slower the velocity reached for a given metabolic potential (i.e., VO_2max and AVR).

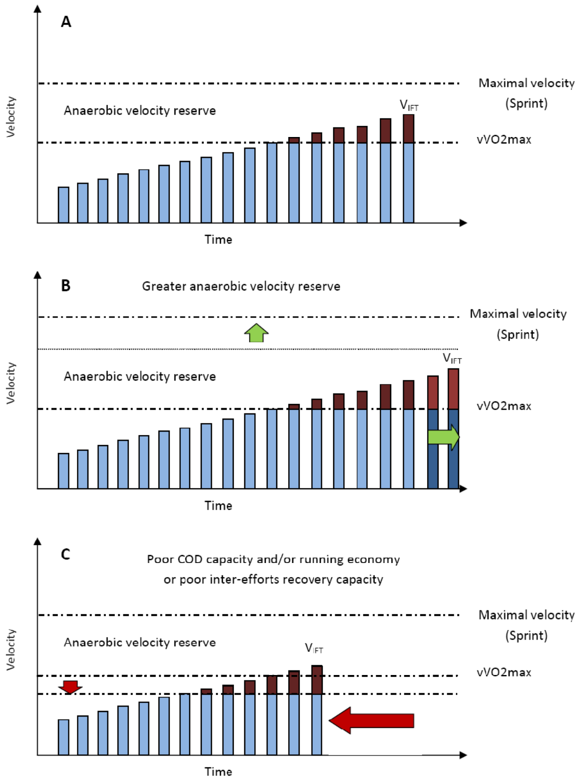

Figure 6. Illustration of the importance of the Anaerobic Velocity Reserve (AVR), COD and inter-effort recovery abilities in the attainment of V_{IFT}. Panel A: once vVO_2max is reached, the additional energy provided during the following stages is derived from anaerobic sources. Therefore, for a given vVO_2max, the greater the AVR (or at least the greater the proportion used), the greater the number of 'supra-vVO_2max' stages completed (and the faster the V_{IFT}). Panel B : this player having a greater AVR is able to reach, for a similar vVO2max, two more stages during the 30-15$_{IFT}$ (1 km/h). Since the AVR (or the proportion used) influences also what can be done during high-intensity intermittent runs, the use of the V_{IFT}, and not vVO2max, enables to programming a similar (anaerobic and neuromuscular) workout load for each player. Panel C illustrates the importance of COD abilities and/or inter-effort recovery abilities on the V_{IFT} reached, since both influence directly the energetic cost of running during the test. As demonstrated in Figure 1, running economy determines the speed reached for a given VO2max (and also AVR), so that a player with a poor COD will have a greater energetic cost of running and will present a lower vVO2max and therefore, a slower V_{IFT}. Similarly, poor inter-effort recovery ability will be associated with a steeper VO_2/velocity relationship and/or premature muscular fatigue, which will also lead to slower running velocities. As for AVR, V_{ITF} takes into account COD and inter-effort recovery abilities and enables a more accurate tool to adjust training distances on these individual qualities.

Practical validity and accuracy of the test for individualizing interval-training sessions. The second part of the validation process of the test was to show that, compared with the velocities reached after continuous and straight-line tests, using the V_{IFT} as a reference velocity for programming interval-training sessions leads to more accurate and homogenous physiological responses. To do so, we compared HR responses to intermittent shuttle-runs (i.e., at 120% de vVO_2max), which running distances were set either based on V_{IFT}, or V_{L-B}. Given the differences in absolute running velocities, percentages were adjusted accordingly: either 95% of V_{IFT} or 110% of V_{L-B} (Figure 7). As expected, the inter-player variability of the HR responses was substantially lower when V_{IFT} was used as the reference speed (3 vs. 9% of inter-individual variations). This again exemplifies the validity of the test to schedule high-intensity intermittent shuttle-runs (7).

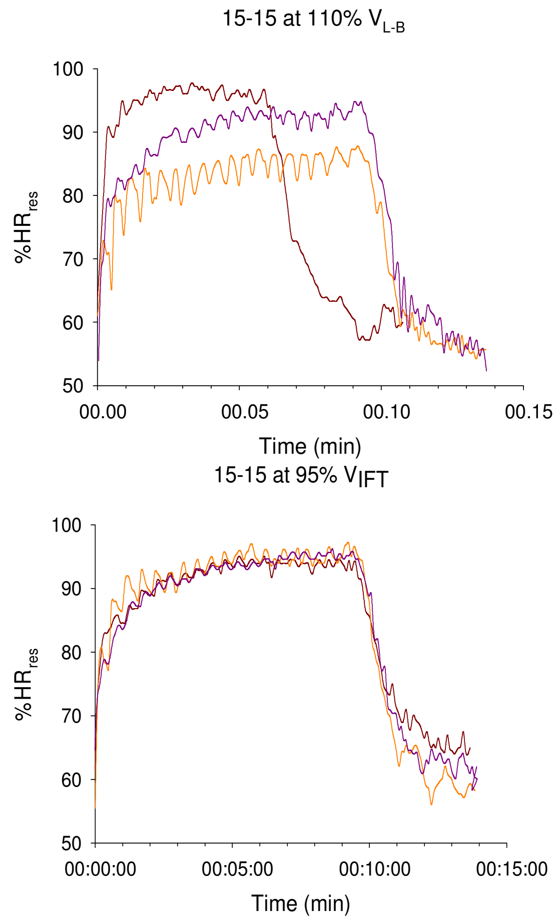

Figure 7. Heart rate responses (HR, expressed as a percentage of HR reserve) in three representative professional handball players during two high-intensity intermittent shuttle-runs (15''-15''), performed with either V_{L-B} (upper panel) or V_{ITF} (lower pannel) as the reference running velocity. It clearly appears than HR responses are much more homogenous with V_{IFT} used as the reference speed.

VI. Applications of the 30-15$_{IFT}$ for intermittent sport players.

As mentioned in the introduction, and given the previous demonstration (validity section), V_{IFT} is meant to be used:

VI. 1. As a reference velocity for individualizing high-intensity interval training including COD (7). Since the attainment of V_{IFT} is simultaneously related to maximal aerobic function, anaerobic capacity (or at least the proportion of AVR used), neuromuscular and COD qualities and inter-effort recovery abilities (6, 7), it reproduces and evaluates the physical capacities that are taxed during high-intensity interval training including COD. V_{IFT} is therefore a composite velocity, which takes into account all physiological variables elicited when performing shuttle intermittent runs. **The 30-15$_{IFT}$ is highly specific, not to the sports, but to the training sessions commonly performed in intermittent sports.** In this line, it is worth noting that the velocity obtained via continuous and straight-line tests (e.g., V_{L-B}) is still well suited to schedule submaximal continuous and straight-line runs (e.g., 20-min run at 80-85% of V_{L-B}).

Percentages of V_{IFT} to use for scheduling interval-training sessions. As mentioned earlier, V_{IFT} is 2-5 km/h faster than the velocities reached at the end of the other popular continuous field tests (11, 15); it is therefore necessary to adjust the percentages of V_{IFT} used when scheduling training sessions (i.e., lowered, Figure 7). While high-intensity intermittent shuttle-runs are generally performed above vVO_2max (i.e., 110-120% for a 15''-15'' with passive recovery), V_{IFT} constitute the upper limit for these exercises (i.e., 100% - except for all-out repeated-sprint sequences). Therefore, depending on the various combinations between the intensity and the duration of exercise and recovery periods, exercise modality (e.g., running with or without COD, ground surface) and series duration, intervals can be set at intensities ranging from 85 et 100% of V_{IFT} (Table 1). For more information, several articles (most in French but still explicit for non-French readers) are available at http://www.martin-buchheit.net (9, 11, 12, 31) and provide a detailed description of appropriate intensities to use for high-intensity intermittent shuttle-runs based on the V_{IFT}.

VI. 2. To evaluate the overall athletic fitness of players during the season. Again, since the V_{IFT} reflects simultaneously maximal aerobic function, anaerobic capacity (or at least the proportion of AVR used), neuromuscular and COD qualities and inter-effort recovery abilities (6, 7). Tracking changes during the season can be used to monitor a team sport-specific players' fitness level.

a. The disadvantage is that, with the unique use of the $30\text{-}15_{IFT}$, it is impossible to isolate any physical quality, as would be done with a test battery (idea of an athlete profiling).

b. The advantage is that one test is enough for an overall picture. In this line, in professional handball players, V_{IFT} increased significantly between the start of the preparatory phase and the start of the competitive phase, without any further alteration during the competitive season (Figure 8) (10). In more controlled studies in young handball players, V_{IFT} showed improvements in 6 to 10 weeks of 5 (16) to 9 (21) % after high-intensity intermittent shuttle-runs (with the individualization of running distances based on V_{IFT} obviously!), of 6% after game-based training (i.e., small-sided games (16)), and of 5% after short (21) and longs (20) repeated sprints. However, it is worth noting that all these studies were performed in-season, so several other factors might have also contributed to the observed changes in V_{IFT} (e.g., handball training session, strength sessions, and club games).

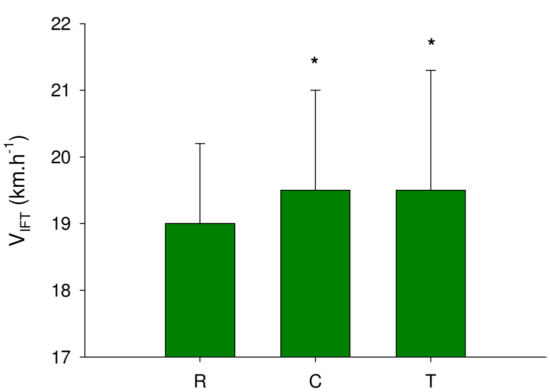

Figure 8. Changes in V_{IFT} during a competitive season in a professional handball team (French first league) (R : start of the preparatory phase [end of July], C : start of the competitive phase [September] et T : after Christmas break [January]) (10). *: significant difference vs. R (*P*<0.05)

VI. 3. To improve a player's profiling when combined with results obtained from additional tests

a. **Isolating inter-efforts recovery ability.** Comparing the V_{IFT} with the velocity reached on a modified continuous version of the $30\text{-}15_{IFT}$ (i.e., performed exactly similarly to the original test, but without recovery periods), enables the isolation of inter-effort recovery ability (27). Simply, the greater the difference between the two velocities, the better the recovery ability. In moderately-trained team-sport players, the mean velocity difference was found to be +3.6 ± 0.8 km.h^{-1}. We then estimated that a velocity difference greater than 4 km/h (20%) might be indicative of a good (i.e., at least 'large', based on Cohen's effect size principle) inter-efforts recovery ability; conversely, a velocity difference smaller than 3 km/h (15%) might reflect a poor recovery ability.

b. **Isolating COD ability.** Comparing the V_{IFT} with the velocity reached on a modified straight-line version of the $30\text{-}15_{IFT}$ (i.e., performed exactly similarly to the original test, but on a track without COD), enables the isolation of COD ability (27). The smaller the difference between the two velocities, the better the COD ability. The mean velocity difference was -2.0 ± 1.2 km.h^{-1}. We estimated that players displaying a velocity difference greater than 3 km/h (15%) might present a poor (i.e., largely worse than the average) COD ability; conversely, a difference lower than 1 km/h (6%) might be indicative of a good COD ability.

c. **Assessing intermittent endurance capacity.** When completed with intermittent shuttle-runs performed until exhaustion at different percentage of V_{IFT}, the $30\text{-}15_{IFT}$ can also be used to evaluate a specific intermittent endurance capacity. The reliability of such exercises is good (15%, unpublished observations). As previously shown for submaximal continuous exercise (33), and as illustrated in Figure 9, the slope of the intensity vs. time to exhaustion (log-transformed to make the relationship linear) relationship provides the "Intermittent endurance Index" (17) (iEI, the steeper the slope, the worse the endurance). While V_{IFT} reflects an intensity-related limit for high-intensity intermittent exercise, iEI exemplifies a players ability to sustain sub-to maximal intensity intermittent efforts as during games, and can be used to optimize and individualize the duration of interval-training series (Figure 8) (16, 17). For example, instead of having all players performing intermittent runs for 8 min, those displaying the better iEI (or greater times to exhaustion at a given percentage of V_{IFT}) may run for 10-12 min, while those having poor iEI (or a short time to exhaustion) could run 5-6 min only. Another practical way of individualizing series is to use 70% of the time to exhaustion at a given intensity, i.e., for a player with a time to exhaustion of 10 min, we can propose 2 x 7-min series (empirical observations). Finally, the assessment of both times to exhaustion and iEI has been shown to be sensitive tools to monitor a player's fitness status, since both times to exhaustion and iEI were improved after a training period including small-sided games in young handball players (Figure 9) (16).

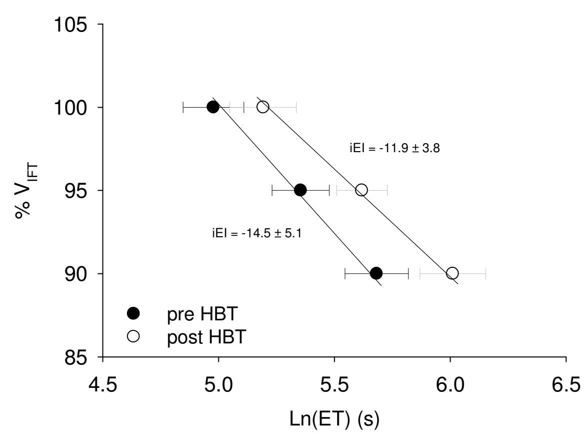

Figure 9. Changes observed in times to exhaustion during high-intensity shuttle intermittent runs performed at different percentage of V_{IFT} after a training period including small-sided games (2 x 3-4 min a week, 4 vs.

4) in young handball players (16). While the right-shift of times to exhaustion exemplifies a better ability to sustain intermittent efforts at a given absolute velocity, the lowering of the slope reflects an improved overall endurance, i.e., a better ability to sustain exercise intensity despite the lengthening of exercise duration.

VI.4 Extension of the original protocol for Basketball and Ice Hockey. While the test is definitively non sport-specific (but specific to interval-training sessions), we developed two protocols to better fit the demands of Basketball and Ice Hockey. For Basketball, we have restricted the shuttle length to 28 m, so that the test can be set on the Basketball field to save time (using directly the red lines (28)). This protocol is also of interest for practitioners willing to implement the 30-15_{IFT} in small gymnasiums and do not have a 40-m field. This shortening of the shuttle-runs does not modify the physiological responses, neither the V_{IFT} reached (28). In the same line, we also developed the 30-15 Intermittent Ice Test (30-15_{IIT}) for Ice Hockey. While we kept the original 40-m shuttles, we modified the velocity increments to make it compatible with the specificity of ice skating (Figure 10). This test has also been shown to be valid, reliable and useful to monitor changes in ice skating-specific fitness (19).

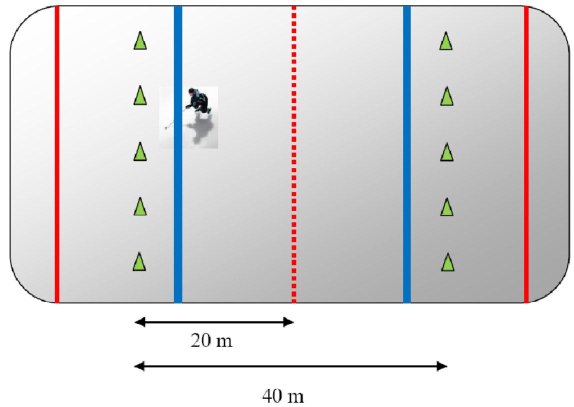

Figure 10. Area prepared for the 30-15 Intermittent Ice Test (30-15_{IIT}).

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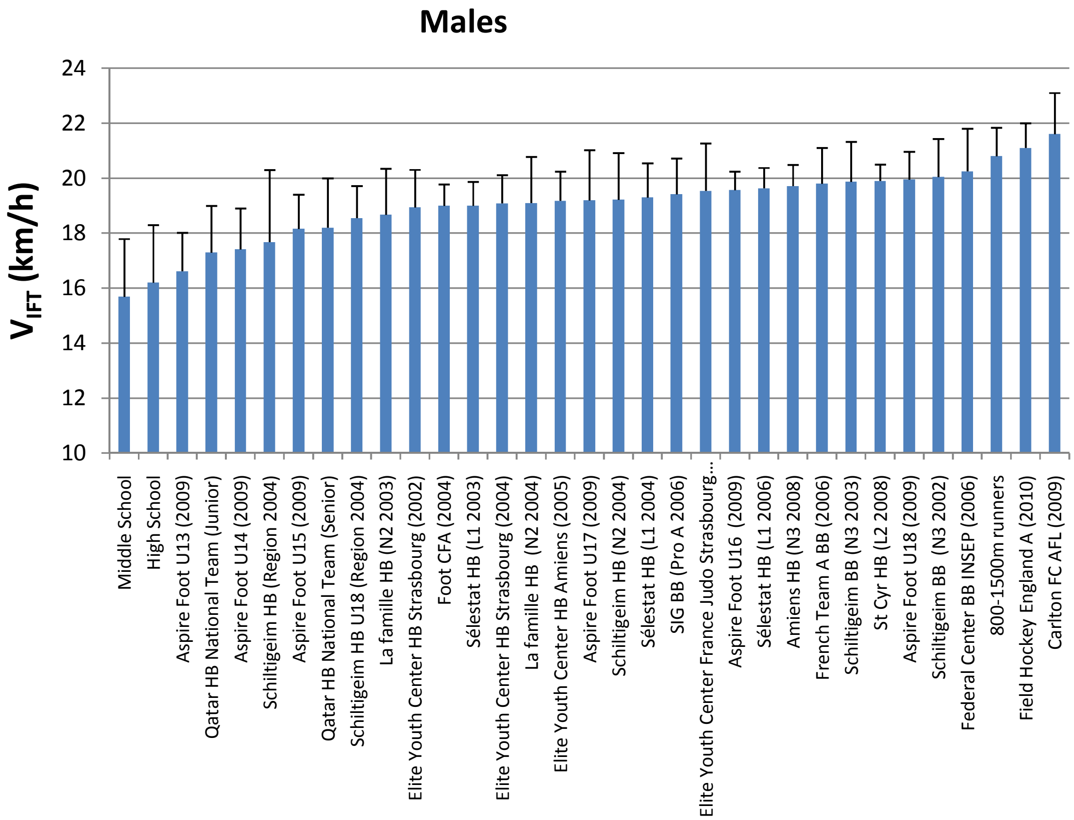
Running time	Running intensity (%V_{IFT})	Recovery duration	Recovery intensity (% V_{IFT})	Running modality	Max series duration	Number of series	Recovery time Between series
3'	85-88%	-	-	Straight line	-	5 to 6	3'
45"	90%	15"	passive	Straight line	7'-8'	2 to 3	3'
30"	90%	15"	passive	Straight line	7'-8'	2 to 3	3'
30"	90%	30"	40%	Straight line	>12	2	3'
30"	93%	30"	passive	Shuttle 40m	10'-12'	2 to 3	3'
15"	100%	15"	passive	Straight line	10'	2 to 3	3'
15"	95%	15"	25%	Shuttle 40m	15'	2	3'
20"	95%	20"	passive	Straight line	7'-8'	2	6-7' active
20"	90%	20"	45%	Shuttle 30m	7'-8'	2	6-7' active
20"	95%	15"	passive	Shuttle 30m	7'-8'	2	6-7' active
15"	100%	15"	passive	Shuttle 40m	7'-8'	2	6-7' active
15"	95%	15"	25%	Straight line	7'	2	6-7' active
15"	95%	10"	passive	Shuttle 40m	7'	2	6-7' active
10"	90%	10"	passive	Shuttle 10m	6'	2	6-7' active
10"	95%	10"	passive	Straight line	6'	2	6-7' active
3"	sprint	17"	passive	20m sprint or 2 x 10m Shuttle	6'	2	6-7' active

Table 1. Examples of high-intensity intermittent shuttle-runs with V_{IFT} used as a reference speed to individualize running distances.



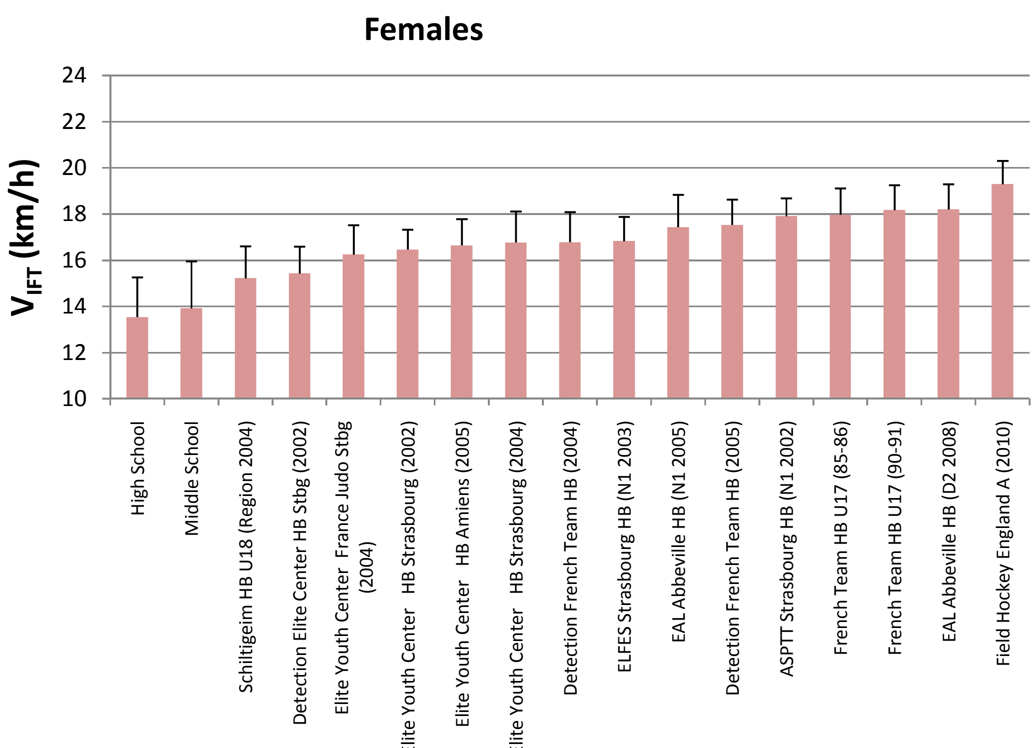


Figure 11. V_{IFT} values measured for different teams (male and female) in different sports and competing at various levels.

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