Wales Anaerobic Test: Reliability and Fitness Profiles of International Rugby Union Players

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Title: The Wales Anaerobic Test (WAT): Reliability and fitness profiles of international Rugby Union players

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ABSTRACT

In order to provide strength and conditioning coaches a practical and evidence-based test for repeated-sprint ability in rugby union players, this study assessed the relative and absolute test-retest reliability of the Wales Anaerobic Test (WAT) and its position-specific association with other fitness performance indices. Thirty-four players (forwards: n = 19; backs: n = 15) of the Welsh rugby union male senior national team performed the WAT (10 × 50-m distance, 25-30 s of passive recovery) twice within 4 days. Time for each repetition was recorded, with the best (WAT_{Best}) and total time (WAT_{TT}) retained for analysis. Relative (intra-class correlation coefficient, ICC) and absolute (standard error of measurement, SEM) reliability of the WAT indices were quantified. Further, association (Pearson's product–moment correlations and stepwise backward elimination procedure) with other fitness performance indices [10-m and 40-m sprinting times, 30-15 intermittent fitness test ($30\text{-}15_{IFT}$) and Yo-Yo intermittent recovery test level 2 (YYIR2)] was investigated. Pooled values revealed *"moderate"* to *"high"* ICCs for WAT_{Best} (ICC = 0.89, P = 0.626) and WAT_{TT} (ICC = 0.95, P = 0.342). Good test sensitivity was reported for forwards and backs' WAT_{TT} (P > 0.101). Both WAT_{Best} and WAT_{TT} correlated with 10-m and 40-m sprinting times (r > 0.69, P < 0.001) as well as with $30\text{-}15_{IFT}$ (r < -0.77, P < 0.001) and YYIR2 (r < -0.68, P < 0.001) for pooled values. The WAT proved to be a reliable and sensitive test to assess the rugby union specific repeated-sprint ability related fitness of international players.

Keywords: High-intensity running; Repeated-sprint ability; Anaerobic capacity; aerobic power; Team sports.

INTRODUCTION

Rugby union is an intermittent team sport that requires many different physical qualities during a match (13, 31). This sport requires a sufficient aerobic capacity which can be seen with players running up to 6000 m for backs and 5200 m for forwards (31), while exhibiting high levels of repeated high-intensity activities such as accelerations, decelerations, sprinting (3, 12, 14, 31), and also combative movements such as tackling, rucking and mauling (13, 32). Further, repeated-sprint ability (RSA) has been described as a very important determinant of the match result (12, 13, 35) and may contribute to ensuring that players are able to repeat specific activities such as rucks, mauls and getting to breakdowns quicker than their opponents. Therefore, evaluating and monitoring RSA-related qualities of rugby union players would be relevant for coaches and background staffs, not only to assist the development of strength and conditioning programs but also to differentiate playing positions and standards (3).

By definition, RSA has been described as short "all-out" sprinting efforts of <10 s with brief recovery times <60 s (17). Due to its "all-out" nature, developing RSA is complex. Both neuromuscular (neural drive or motor unit recruitment) and metabolic (aerobic capacity, phosphocreatine resynthesis, hydrogen buffering) components are thought to contribute to RSA performance (17, 18, 36). Further, RSA-induced fatigue development has been shown to be task dependent, with exercise mode, specificity, effort duration, recovery time and type (passive or active) impacting the physiological response (4, 17). Therefore, evaluating RSA for rugby union would require the incorporation of rugby union-specific movements.

Several field tests [*e.g.*, 30-15 intermittent fitness test (30-15$_{IFT}$) (25), Yo-Yo intermittent recovery test level 1 (YYIR1) or 5-m multiple shuttle test (5-m MST) (33)] have been used extensively to evaluate the fitness standards of rugby union players. While these field tests are reliable, they may not evaluate or capture the specific high-intensity actions of the sport. Only few studies have looked at specific tests in rugby union. Reportedly, Austin et al. (1) considered a 3 repeated high-intensity exercise tests for rugby league and rugby union players, and Smart et al. (35) used the rugby-specific repeated-speed test (RS2). To the best of the authors' knowledge, apart from the RS2 implemented exclusively in New Zealand, the other specific tests are not widely used in professional rugby union. In a recent review of strength and conditioning practices in both the northern and southern hemisphere in rugby union (26), the Wales Anaerobic Test (WAT) was referred as a rugby-specific fitness test and has been used both as an assessment and training tool for the development of repeated high-intensity effort ability by the Welsh Rugby Union for the senior international team, national age grade and regional club players as well as with the British and Irish Lions team in 2013. According to Nicholas et al. (19), the WAT (*i.e.*, 10 × 10-15 s efforts over a 50-m distance, interspersed by 25-30 s of passive recovery) would be representative of rugby union match time motion analysis (*i.e.*, 5-15 s of intensive efforts interspersed by <40 s of recovery). Because RSA test alone may underestimate the repeated high-intensity demands of rugby union (19), using tests that replicates/mimics rugby union locomotor demands appears relevant to provide useful information for strength and conditioning coaches and background staffs. Despite the interest of this novel test and its growing popularity in the rugby community, no study has examined the construct validity of the WAT and its associations with other fitness qualities such as maximal sprinting velocity or aerobic capacity.

Therefore, the aims of this study were twofold: (i) to assess the relative and absolute test-retest reliability of the WAT in elite rugby union players, and (9) to investigate its position-specific association and criterion validity with other fitness performance indices. We hypothesized that the WAT would be a reliable test and would be associated with field-based tests. We also expected a position-specific dependency among reliability and correlations/predictions.

METHODS

Experimental approach to the problem

This study was completed in two phases. First, the test-retest reliability of the WAT was determined by having players perform the WAT twice within 4 days, at the same time of day. Relative and absolute reliability was examined using intra-class correlation coefficient (ICC) and standard error of measurement, coefficients of variation (CV) and 95% limit of agreement (LOA), respectively. Second, their position-specific association with other fitness performance indices was investigated using Pearson's product–moment correlations and multiple linear regression models.

Subjects

Thirty-four international-level players (forwards: n = 19, 28.8 ±3.5 yr, 190.6 ±6.7 cm, 115.2 ±5.6 kg; backs: n = 15, 26.3 ±2.6 yr, 183.5 ±7.4 cm, 90.5 ±8.8 kg) belonging to the Welsh rugby union senior male national team participated in the study as part of their normal national squad training schedule in preparation for the Six Nations rugby union tournament. All players were informed of all procedures and gave their written and informed consent for data collection. The study was approved by the local ethics committee and carried out in accordance with procedural requirements (19) and the declaration of Helsinki.

Procedures

The present study was performed in 4 sessions. Data were first gathered on the absolute and relative reliability of the WAT where each player performed the WAT twice at the same time of day (14:00-16.00 h) to minimize the effects of diurnal variation, with a maximum of 4 days between the tests. On a separate occasion (within 2 weeks), straight-line 40-m sprint was performed and followed after 1 h of rest by the $30\text{-}15_{IFT}$ or YYIR test level 2 (YYIR2) in a randomized and counter-balanced order. The remaining test (30-15IFT or YYIR2) was conducted in the next days with at least 48 h apart. All players were familiarized and habituated to the test protocol, arising as a condition of their duties. All tests were performed at the Welsh rugby union national center of excellence on a 4-G artificial grass surface in-doors (ambient temperature 22-25°C, relative humidity 50-60%). Players were instructed to wear the same footwear for all sessions and were allowed to complete a 15-min standardized warm-up of low-intensity running drills interspersed with eight dynamic stretch routines and strides followed by two submaximal sprints efforts, with 3 min passive rest before beginning assessment. Being in supervised training camp, sleep, diet (caffeine-free beverage >3 h before testing) and training load (avoiding strenuous session in the preceding 24 h) were carefully controlled.

Wales Anaerobic Test (WAT)

The WAT protocol consisted of 1 set of 10 repetitions over 50 m, completed maximally on a rolling clock of every 40 s (exercise:recovery ratio of 1:3-5 with efforts ranging 10-15 s and recovery periods of 25-30 s), thereby mimicking rugby union match activity (29). Players completed the WAT in lanes, with each individual lane marked by 4 cones set out as follows (figure 1): cone 1 positioned 2 m behind the starting line. On the master whistle, players completed an "up-down" between cones 1 and 2 with their chest on the ground while being required to touch the *gluteal* muscles with each hand before getting up. The players then completed a figure of eight around cones 2 and 3, and once they came around cone 2, they sprinted forth (up to cone 4) and back (cone 2) at which the time was recorded for the completed repetition.

For each test, the best time (WAT_{Best}, always the first repetition) was determined and subsequent repetition time added up to give a total time score (WAT_{TT}). Video recordings obtained by means of a Sony HD camera (HDR-HC9E) were analyzed using Dartfish 5.0 (Dartfish, Fribourg, Switzerland) to calculate sprint times (from start from foot lift-off to finish line).

*** Figure 1 about here ***

Straight-sprinting test

Players were asked to run a maximal, straight-line 40-m sprint. Dual-beam electronic timing gates (Swift, Wireless Speedlight Timing System, Queensland, Australia) were used to record split time at 10-m and overall 40-m sprint time to the nearest 0.01 s. The start commenced from a standing static position with their preferred front foot 0.5 m behind the first timing gate and were instructed to sprint as fast as possible over the 40-m distance. The height of the photocells was adjusted according to the height of the participant's hip (sprinting order were defined a-priori to avoid photocells' over-manipulation). Two trials with 3 min of passive recovery were completed, and the best performance was kept for analysis.

$30\text{-}15_{IFT}$

The test consisted of 30-s shuttle runs over 40 m, interspersed with 15 s of passive recovery and was performed as previously described (8). The starting speed was set at 8 $km.h^{-1}$ for the first 30-s run and was increased by 0.5 $km.h^{-1}$ every 45-s stage thereafter. The speed of the test was controlled by an audible signal (via a portable audio player with loudspeaker adjusted so all players could clearly hear the instructions) that beeped at appropriate intervals, whereby players were to be within a 3-m tolerance zone at either end or the middle of the 40-m shuttle.

Players were instructed to complete as many stages as possible, with the test ended when they could no longer maintain the imposed running speed or when they failed to reach the tolerance zone on 3 consecutive occasions. The last completed stage was noted as V_{IFT} (8).

Yo-Yo Intermittent Recovery Test Level 2

As previously described (27), the YYIR2 is an incremental running test to exhaustion which consists of 2 repeated 20-m runs back and forth between the starting, turning and finishing lines, at progressively increased speeds (starting at 13 km.h^{-1}), interspersed by 10-s active recovery (2 × 3.5 m jogging) periods and controlled by audio beeps through a portable audio player with loudspeaker. When a player twice failed to reach the finishing line before the next audio cue, the distance covered was recorded as the final test result and converted to the corresponding stage speed level. The YYIR2 has been reported as reproducible (2).

Statistical analysis

Data analyses were performed using Sigmaplot 11.0 software (Systat Software, Inc., San Jose, CA, USA) and a predesigned spreadsheet for reliability analysis (22). Normality of the data was confirmed using the Kolmogorov-Smirnov test. The relative and absolute reliability of the WAT indices were quantified. To determine relative reliability, the ICC was calculated. ICCs >0.90 were considered as *"high"*, 0.80 to 0.90 as *"moderate"*, and <0.80 as *"low"* (37). To test the absolute reliability, the standard error of measurement (34), the CVs (21) and 95% LOA were calculated. The level of agreement between repeated trials (test-retest) was quantified using the 95% LOA method originally described by Bland and Altman (5) . The differences between trials were drawn in relation to the mean values and 95% of the differences were expected to lie between the two LOA that were the mean difference ± 2 SD of the differences, expressed as bias ×÷ random error. In complement, the smallest worthwhile change

(SWC) was determined by rearrangement of Cohen' *d* effect size calculation, where the SWC effect (0.2) was multiplied by the between-subject SD. By comparing SWC with SEM, test sensitivity was determined, using the thresholds proposed by Lexell and Downham (28), When SEM was ≤ SWC, the test's capacity to detect change was considered *"good"*, when SEM was equal to SWC it was considered *"satisfactory"*, and when SEM was ≥ SWC the test was rated as *"marginal"*. To investigate systematic bias, a paired sample *t*-test was conducted to test the hypothesis that the sample means of test and retest values did not differ. The effect size of the difference (*d*) for WAT was determined as: (mean value of trial 2 – mean value of trial 1) / pooled SD. The modified scale by Hopkins (www.sportsci.org/resource/stats) was used for the interpretation of *d*: < 0.2, *"trivial"*; 0.2 – < 0.6, *"small"*; 0.6–1.2; *"moderate*; and > 1.2, *"large"*.

Pearson's product–moment correlations were used to examine the relationships among the various fitness tests. The magnitude of effects was interpreted according to Hopkins et al. (23) as follows: ≤0.1, *"trivial"*; >0.1–0.3, *"small"*; >0.3–0.5, *"moderate"*; >0.5–0.7, *"large"*; >0.7–0.9, *"very large"*; and >0.9–1.0, *"almost perfect"*. Furthermore, multiple linear regression models (stepwise backward elimination procedure) with WAT_{Best} or WAT_{TT} as the dependent variables were used to determine the most relevant position-dependent fitness factors contributing to WAT performance. The r^2 values derived from the multiple linear regression models were converted to *r* values for relationship's magnitude interpretation.

RESULTS

Reliability

Summary results for WAT test and retest are shown in Table 1. Except for backs, residual data for WAT_{Best} test and retest were normally distributed. The relative and absolute reliabilities for forwards and backs were *"low"* with larger SEMs than their respective SWCs, indicating that both were of *"marginal"* value. However, pooled values satisfied the ICC criterion with *"moderate"* relative reliability, confirmed by larger SWC *vs*. SEM. The bias ×÷ random error between the two trials for WAT_{Best} were 0.07×÷0.10 s, -0.02×÷0.14 s and 0.19×÷0.14 s for pooled, forwards and backs, respectively (Table 1 and Figure 2A, B and C).

*** Table 1 about here ***

Residual data for WAT_{TT} test and retest were normally distributed (P = 0.101-0.387), with no significant test-retest bias for pooled, forwards and backs values. The relative reliability was considered *"high"* for pooled and forwards and *"moderate"* for backs. However, all SEMs were lower than their respective SWCs, indicating that all were of *"good"* value for test sensitivity. The bias ×÷ random error between the two trials for WAT_{TT} were -1.34×÷0.73 s, -1.67×÷1.17 s and -0.92×÷0.84 s for pooled, forwards and backs, respectively (Table 1 and Figure 2D, E and F).

*** Figure 2 about here ***

Correlations and multiple regression analysis

Figures 3, 4, 5 and 6 present the relationships between WAT with the different standard fitness performance indices. WAT_{Best} was significantly correlated with 10 m and 40 m sprinting times for forwards (r = 0.46, "*moderate*", P = 0.046; r = 0.54, "*large*", P = 0.018, respectively), backs (r = 0.54, "*large*", P = 0.038; r = 0.52, "*large*", P = 0.047) and pooled sample (r = 0.75, "*very large*", P < 0.001; *r* = 0.73, "*very large*", P < 0.001) (Figure 3). Correlations were also found between WAT_{TT} and 10 m and 40 m sprinting times for forwards (*r* = 0.53, "*large*", P = 0.020; *r* = 0.51, "*large*", P = 0.026) and pooled sample (*r* = 0.73, "*very large*", P < 0.001; *r* = 0.69, "*large*", P < 0.001) but not for backs (*r* = 0.28, "*small*", P = 0.319; *r* = 0.37, "*moderate*", P = 0.171) (Figure 4).

*** Figures 3 and 4 about here ***

"*Large*-to-*very large*" relationships were observed between WAT_{Best} and WAT_{TT} with 30-15_{IFT} (*r* = -0.80, "*very large*", P < 0.001; *r* = -0.77, "*very large*", P < 0.001) and YYIR2 (*r* = -0.70, "*large*", P < 0.001; *r* = -0.68, "*large*", P < 0.001) performance for pooled values. Backs showed significant correlations between WAT_{Best} and WAT_{TT} with 30-15_{IFT}, and only WAT_{TT} with YYIR2 (Figures 5 and 6).

*** Figures 5 and 6 about here ***

The stepwise multiple regression analysis (Table 2) showed that a combination of 40-m sprinting time and 30-15_{IFT} performance explained ~76 % of the variance in WAT_{Best} for pooled sample (model 1, *r* = 0.87, r^2 = 0.76, "*very large*", P < 0.001). Interestingly, selected determinants changed depending with position: 40-m sprinting time for forwards (model 2, *r* = 0.54, r^2 = 0.29, "*large*", P = 0.018); 10-m sprinting time and 30-15_{IFT} performance for backs (model 3, *r* = 0.76, r^2 = 0.58, "*very large*", P = 0.005).

With WAT_{TT} as dependent variable, 10-m sprinting time (P = 0.002) and 30-15_{IFT} performance (P < 0.001) account for the greater proportion of total variance for overall (model 4, *r* = 0.84,

r^2 = 0.70, "*very large*", P < 0.001) (Table 2). However, 40-m sprinting time appears as the sole determinants for forwards (model 5, r = 0.51, r^2 = 0.26, "*large*", P = 0.026), whereas 30-15_{IFT} performance was the one retained for backs (model 6, r = 0.61, r^2 = 0.37, "*large*", P = 0.016).

*** Table 2 about here ***

DISCUSSION

The main purpose of this study was to determine the relative and absolute reliability of the WAT in international rugby union players and to investigate its position-specific association and criterion validity with other fitness performance indices. Our findings indicated that the WAT is a reliable and sensitive tool to assess the rugby union specific RSA-related fitness of international players. Results also showed that WAT_{TT} is a more reliable measure (*"moderate"* to *"high"* ICCs) than WAT_{Best} *("low"* ICCs). Furthermore, the WAT correlated with several other fitness indices such as sprint times and team-sport aerobic fitness field-based tests. Interestingly, both Pearson's product–moment correlations and multiple linear regression models (stepwise backward elimination procedure) indicated position-specific dependence. Although correlation does not imply causality, this may provide some practical insights for coaches and background staffs.

In the present study, ICCs for WAT_{Best} and WAT_{TT} were *"moderate"* to *"high"* for pooled and forwards, and deemed *"acceptable"* for backs. Since it is affected by sample heterogeneity (5), ICC cannot be used as the sole statistical measure of reliability. Consequently, it is recommended that absolute measures of reliability, such as CV and LOA would also be determined in conjunction with the ICC (24). As checked by Bland and Altman plots, test-retest reliability and measurement errors were comparable between the samples. In these analyses, both bias and random error were found to be low. However, both pooled and forwards values showed larger CVs than backs, which may be due to the large variability in anthropometrical characteristics and body composition (20) as well as position-specific demand (3) generally observed between playing positions We conclude that the WAT could be used with international rugby union players with a higher reliability for backs. To be interpreted as genuine and not consequential to random performance fluctuation or "noise" (21), a training-induced change need to exceed 2.81% and 1.81% / 3.50% and 1.74% for WAT_{Best} and WAT_{TT} in forwards and backs, respectively. In the particular context of international rugby union competition where RSA requirements significantly increase from professional club to senior international games (3), the WAT would be relevant in the selection process and competition preparation.

One may also assume that WAT_{Best} was less reliable than WAT_{TT}. A close examination of the likelihood that the true values of estimated differences in WAT outcome would be substantial (*i.e.*, larger than the SWC) showed that the SWC for pooled, forwards and backs were greater than their SEMs for WAT_{TT} only, indicating that this variable only has a good ability to detect real changes in WAT in international rugby union players. A possible explanation for such differences may relate to the nature of the WAT involving a higher mechanical stress and energy expenditure compared to straight-RSA test that did not require repeated accelerations and change of directions (15). Interestingly, irrespective of playing positions, ICCs and CV for WAT_{TT} were similar to those of Austin et al. (1) who tested the reliability and sensitivity of a repeated high-intensity exercise performance in rugby league and rugby union players. While we have focused on directly measured variables, the calculation of sprint decrement or fatigue index would not have led to a higher reliability. In fact, because they incorporate direct measures, sprint decrements indices have been reported to be less reliable (11-43%) than direct measures (2-8%) (1).

Assessing the relationship between the WAT performance and other fitness field-based test is also informative about its criterion-validity. Here, we have observed several significant associations between the WAT variables and sprinting times and $30\text{-}15_{IFT}$ and/or YYIR2. In agreement with previous rugby league and rugby union (1, 38) or Australian football (30) studies having investigated relationship between RSA or repeated high-intensity exercise, WAT_{Best} and WAT_{TT} significantly correlated with sprinting ability, collectively suggesting that fastest players are also those who perform best in RSA efforts. However, WAT_{TT} appears to be position-dependent suggesting a greater emphasis on acceleration for the forwards. As previously demonstrated in international soccer (7), different proportional muscle and skeletal structure between forwards and backs (20) may contribute in the prevalence of neuromuscular qualities to determine RSA. This may also explain the difference between forwards and backs regarding the relationships between WAT variables and team-sport aerobic tests. Accordingly, Darrall-Jones et al. (11) demonstrated that body mass negatively impacts 10-m sprint velocity (r = -0.34 to -0.46) as well as 30-15 IFT (r = -0.59 to -0.79) and YYIR1 (r = -0.65 to -0.74) in English academy rugby union players. The forwards higher body mass may detrimentally affect the constant change of direction over a short distance during the $30\text{-}15_{IFT}$ (10) as well as during the YYIR2.

In the present study, multiple regression analysis showed that 70-76% of the WAT performance can be explained by both sprinting and $30\text{-}15_{IFT}$ performance, with a greater emphasis on sprinting ability for forwards *vs*. aerobic fitness for backs. As for RSA (6, 16), WAT performance may integrate various physiological systems (*e.g.*, neuromuscular, cardiovascular) and metabolic pathways (*e.g.*, anaerobic, aerobic), with most of the energy required being derived from phosphocreatine hydrolysis and anaerobic glycolysis (although their magnitudes are reduced over repetitions). Besides, a higher aerobic contribution is likely to improve between-efforts recovery though a higher tolerance and removal of metabolic by-products (lactate, hydrogen ions) (6). Thus, while it is possible that WAT variables allow the evaluation of international rugby union players' fitness in an integrated way, this also suggests that different position-dependent fitness determinants are at play. According to the aforementioned variability in anthropometrics and body composition among rugby union players (11, 20) as well as position-specific match demands (3), this has implications for strength and conditioning coaches and sport science staffs and how they may program training to positively influence RSA/WAT performance in rugby union players depending on their position. Therefore, specific training could be implemented to reinforce forwards and backs' strengths (based on their respective WAT fitness determinants) or inversely to develop their weaknesses. Future position-specific training studies using WAT must be conducted to validate this contention.

A possible limitation of the present study is the lack of metabolic/physiological measurements. Inclusion of such measures would provide a better understanding of the specific requirements of the WAT. Further, our findings have been limited to a group of international rugby union players. More data is needed to confirm that the WAT protocol is appropriate for assessing the performance of players of different levels of training, age groups and even gender. Because other team sports such as rugby league and Australian football have similar physical demands, further research of the applicability of the WAT in those sports is also warranted.

PRACTICAL APPLICATIONS

The WAT proved to be a reliable test, in particular when expressed as WAT_{TT}. This easy-to-perform test may be considered by strength and conditioning coaches and sport science staffs for inclusion in a testing battery as an accurate rugby union-specific fitness assessment and for probable prescription of position-specific training protocols. Based on position-specific WAT fitness determinants, tailored training program prescription may be an asset for performance optimization. In addition, the WAT performance reported here may be used as normative benchmarks for goal setting, players evaluation/selection in rugby union.

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Figure legend

Figure 1. Visual representation of the Welsh Anaerobic Test (WAT).

Figure 2. Bland and Altman plots for the Welsh Anaerobic Test (WAT) test-retest. A) Pooled values (n = 34), B) backs (n = 16), C) forwards (n = 19) for Welsh Anaerobic Test best time (WAT_{Best}); D) Pooled values (n = 34), E) backs (n = 16), F) forwards (n = 19) for Welsh Anaerobic Test total time (WAT_{TT}). Solid line – bias; dashed lines – 95% limits of agreement (LOA).

Figure 3. Zero-order correlations between the Welsh Anaerobic Test best time (WAT_{Best}) and sprinting times (left panel, 10-m distance; right panel, 40-m distance). Blacks dots are forwards, gray dots are backs, and thick and bold lines are pooled values. Dotted lines are 95% confidence interval.

Figure 4. Zero-order correlations between the Welsh Anaerobic Test total time (WAT_{TT}) and sprinting times (left panel, 10-m distance; right panel, 40-m distance). Black dots are forwards, gray dots are backs, and thick and bold lines are pooled values. Dotted lines are 95% confidence interval.

Figure 5. Zero-order correlations between the Welsh Anaerobic Test best time (WAT_{Best}) and team sport-specific aerobic performances (left panel, 30-15_{IFT}; right panel, YYIR2). Black dots are forwards, gray dots are backs, and thick and bold lines are pooled values. Dotted lines are 95% confidence interval.

Figure 6. Zero-order correlations between the Welsh Anaerobic Test total time (WAT_{TT}) and team sport-specific aerobic performances (left panel, $30\text{-}15_{IFT}$; right panel, YYIR2). Black dots are forwards, gray dots are backs, and thick and bold lines are pooled values. Dotted lines are 95% confidence interval.

Table 1

Table 1. Parameters of reliability analysis for the WAT indices.

	Test	Retest	P-Value	*d*	ICC (95% CI)	CV (%)	Bias	95% LOA	SEM	SWC
WAT_{Best}										
Pooled (n = 34)	13.04±0.63	13.10±0.54	0.626	0.12	0.89 (0.79-0.94)	4.47	1.01	1.28	0.05	0.11
Forwards (n = 19)	13.51±0.36	13.49±0.40	0.854	0.06	0.74 (0.44-0.89)	2.81	1.01	1.40	0.07	0.06
Backs (n = 16)	12.44±0.29	12.62±0.17	0.038	0.75	0.49 (-0.01-0.79)	1.81	1.02	1.47	0.06	0.03
WAT_{TT}										
Pooled (n = 34)	141.61±6.65 s	140.26±6.16 s	0.342	0.21	0.95 (0.90-0.97)	4.54	1.01	1.28	0.36	1.25
Forwards (n = 19)	146.09±5.24 s	144.42±4.94 s	0.319	0.33	0.90 (0.76-0.96)	3.50	1.01	1.40	0.56	0.96
Backs (n = 16)	135.93±2.64 s	135.00±2.21 s	0.263	0.40	0.83 (0.57-0.94)	1.74	1.02	1.47	0.37	0.44

d: Cohen' d; ICC: intra class correlation coefficient; CV: coefficient of variation; LOA: limit of agreement; SEM: standard error of measurement; SWC: smallest worthwhile change.

Table 2

Table 2. Determinants of Welsh Anaerobic Test best (WAT_{Best}) and total time (WAT_{TT}) performance.

Variables	**Coefficient**	**P**	**r^2**	**r**
Stepwise multiple regression - WAT_{Best}				
Model 1 – Overall				
Intercept	12.84	< 0.001	0.76	0.87
30-15	-0.28	< 0.001		
40 m	1.05	< 0.001		
Model 2 – Forwards				
Intercept	8.68	0.018	0.29	0.54
40 m	0.90	0.018		
Model 3 – Backs				
Intercept	12.242	0.005	0.58	0.76
30-15	-0.215	0.014		
10 m	2.777	0.025		
Stepwise multiple regressions – WAT_{TT}				
Model 4 – Overall				
Intercept	134.73	< 0.001	0.70	0.84
30-15	-2.71	< 0.001		
10 m	34.72	0.002		
Model 5 – Forwards				
Intercept	79.76	0.026	0.26	0.51
40 m	12.32	0.026		
Model 6 – Backs				
Intercept	179.997	0.016	0.37	0.61
30-15	-2.211	0.016		

Figure 1

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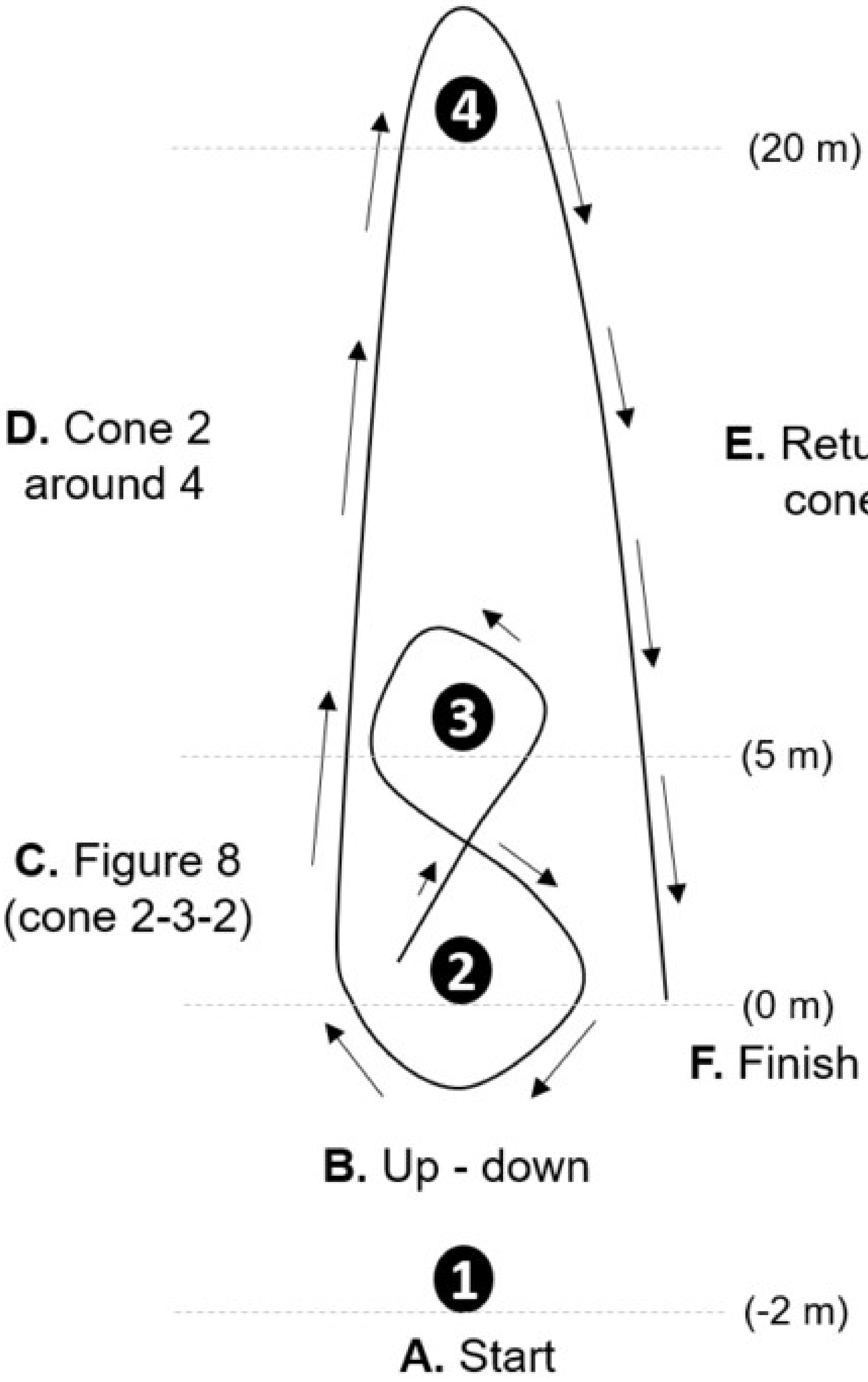

Figure 2

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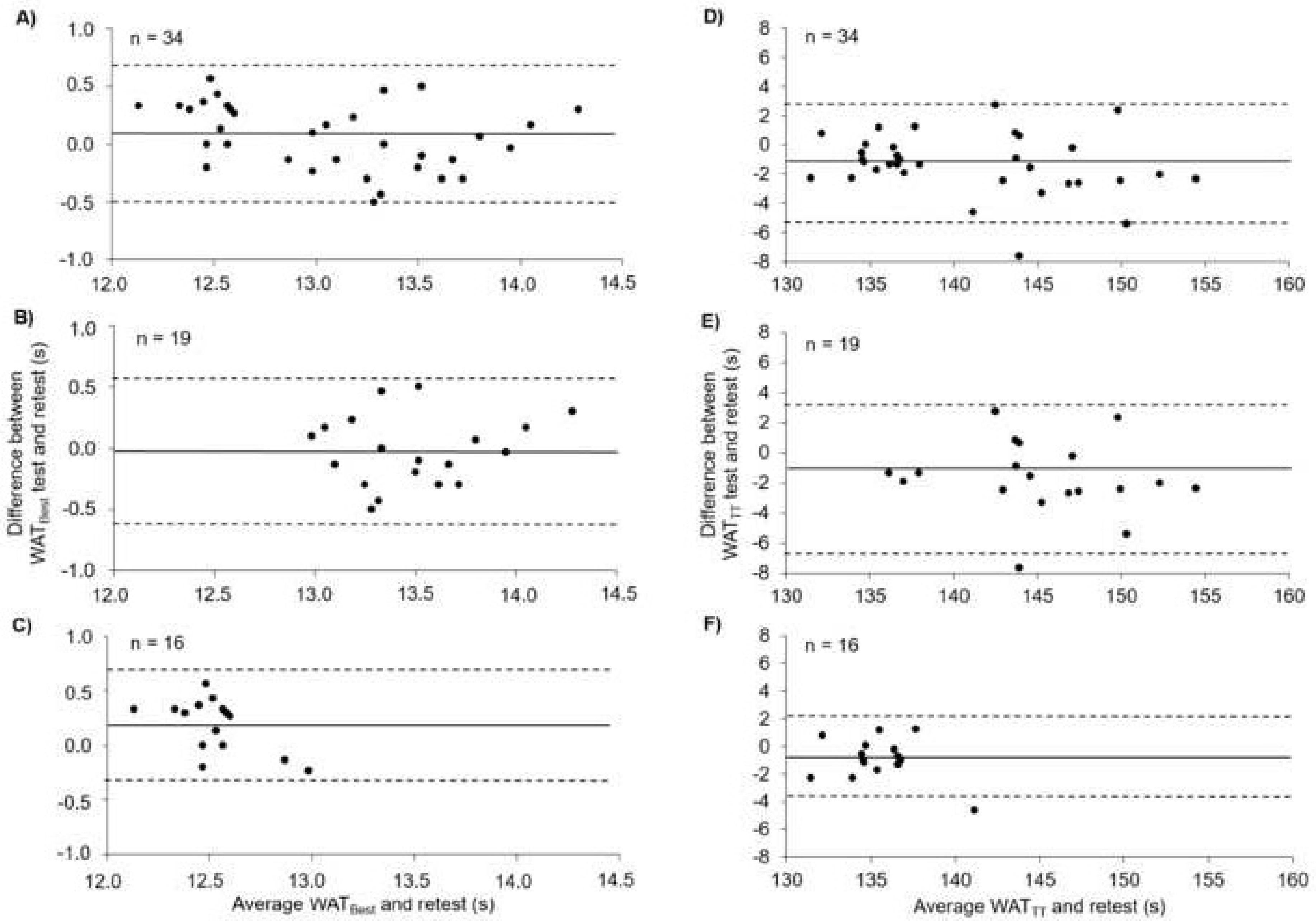

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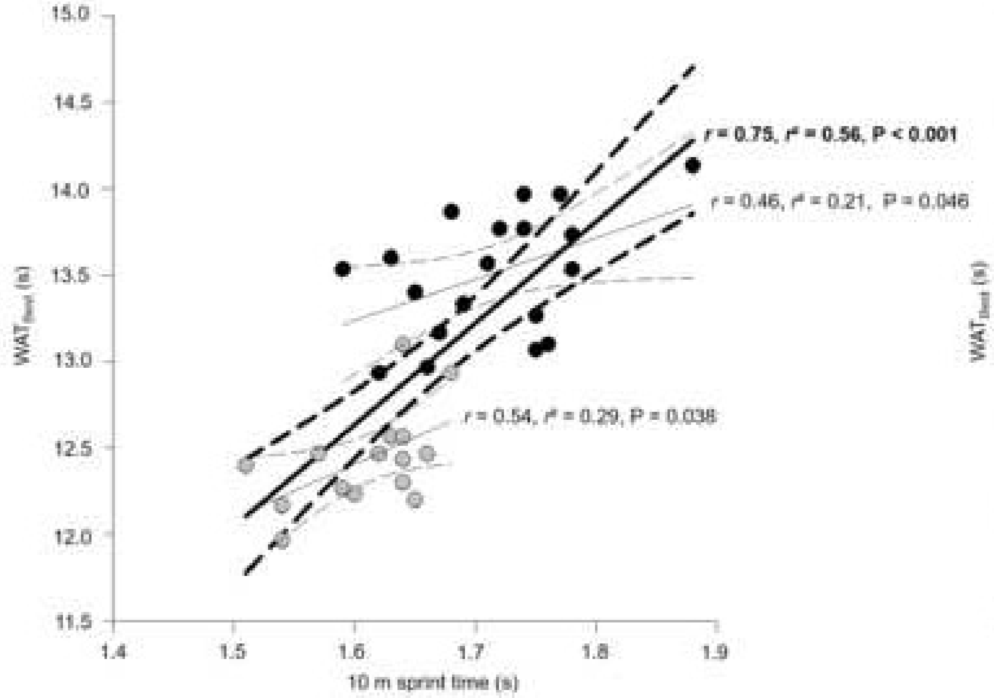

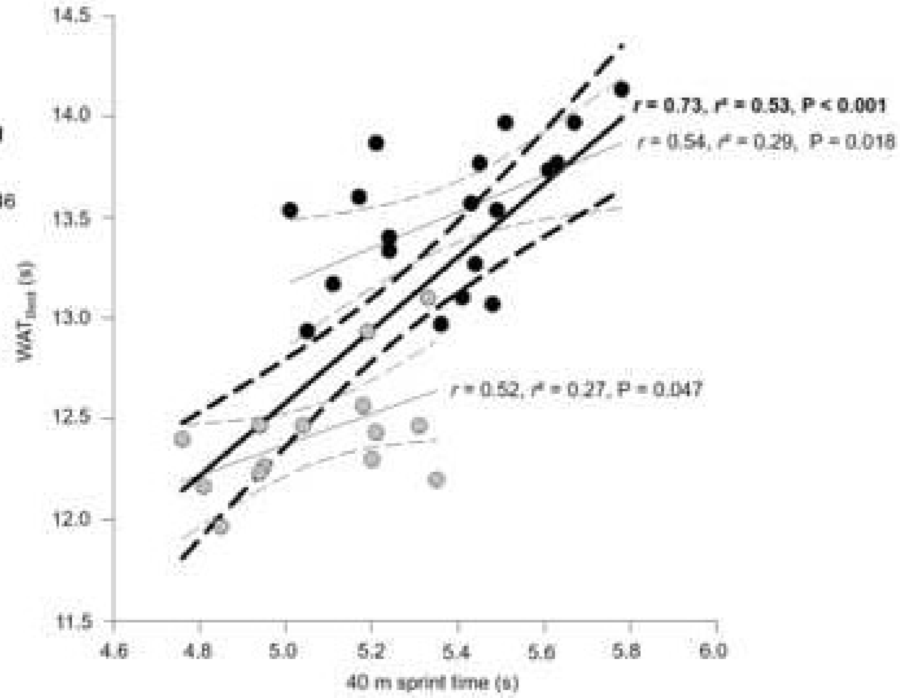

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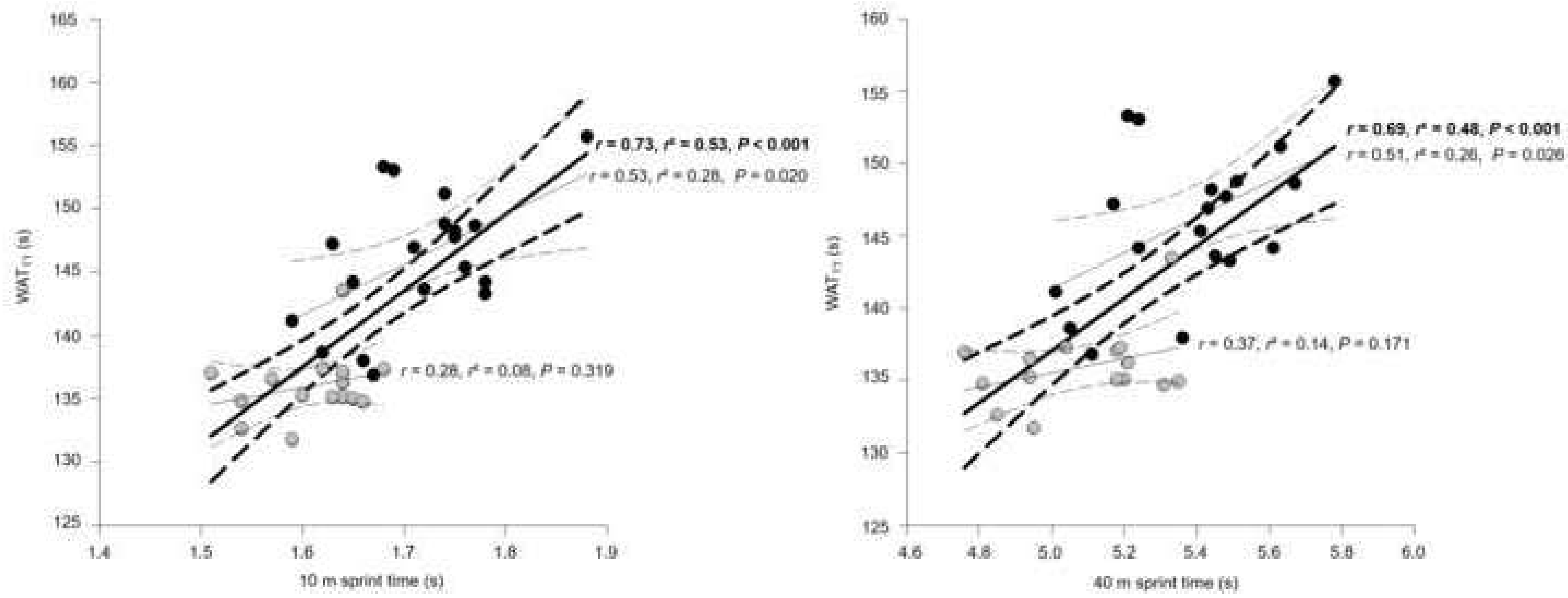

Figure 5

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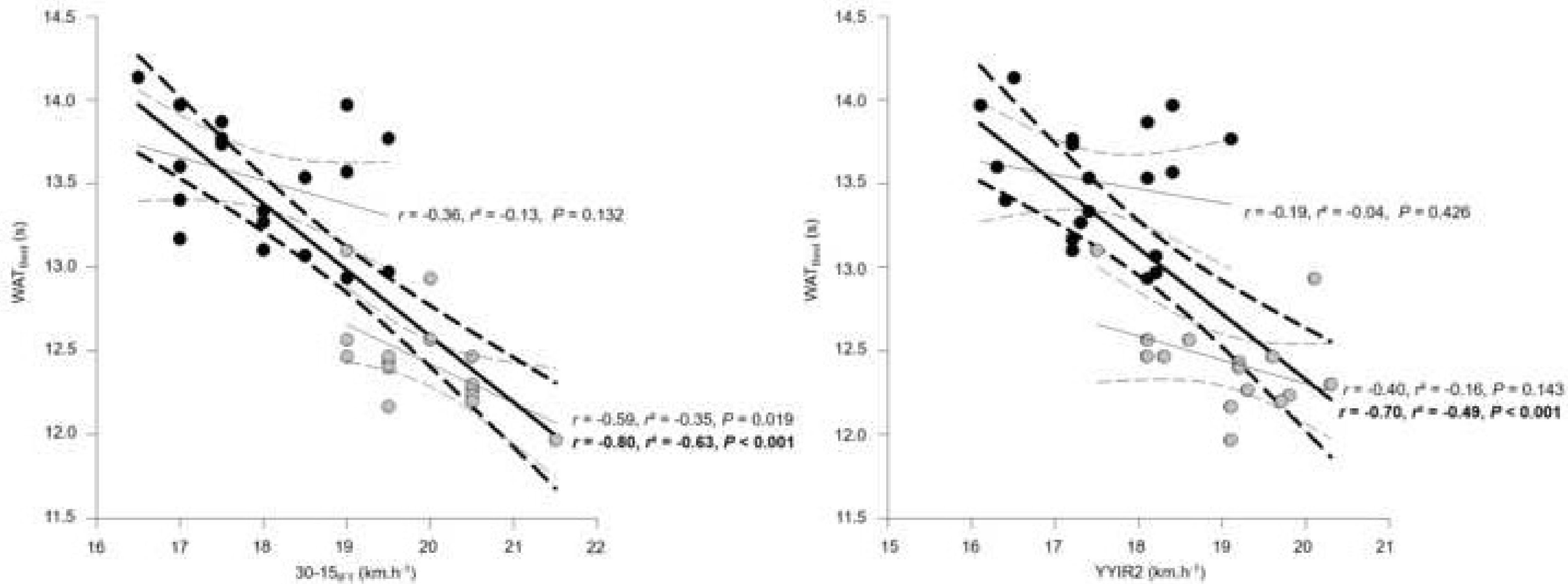

Figure 6

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