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Reliability and criterion-related validity of a new repeated agility test

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ABSTRACT: The study aimed to assess the reliability and the criterion-related validity of a new repeated sprint T-test (RSTT) that includes intense multidirectional intermittent efforts. The RSTT consisted of 7 maximal repeated executions of the agility T-test with 25 s of passive recovery rest in between. Forty-five team sports players performed two RSTTs separated by 3 days to assess the reliability of best time (BT) and total time (TT) of the RSTT. The intra-class correlation coefficient analysis revealed a high relative reliability between test and retest for BT and TT (>0.90). The standard error of measurement (<0.50) showed that the RSTT has a good absolute reliability. The minimal detectable change values for BT and TT related to the RSTT were 0.09 s and 0.58 s, respectively. To check the criterion-related validity of the RSTT, players performed a repeated linear sprint (RLS) and a repeated sprint with changes of direction (RSCD). Significant correlations between the BT and TT of the RLS, RSCD and RSTT were observed ($p<0.001$). The RSTT is, therefore, a reliable and valid measure of the intermittent repeated sprint agility performance. As this ability is required in all team sports, it is suggested that team sports coaches, fitness coaches and sports scientists consider this test in their training follow-up.

INTRODUCTION

Team sports, such as soccer, handball, rugby and basketball, are characterized by high intensity exercise bouts interspersed with periods of sub-maximal effort over matches and training sessions that can last long periods of time [1,2,3,4,5,6,7]. Players perform a variety of explosive movements, such as forward and backward shuttles and changes of direction, and sustain vigorous muscle work [8,9]. Investigations of the specific sprint patterns during competitive games shown that a soccer player performs nearly 1400 activities during a match, including between 150 and 250 brief, intense actions, and achieved 200 displacements at high speed [10]. A basketball player attempts ~105 high-intensity short duration bouts with one occurring on average every 21 s of live time [11]. Similarly, a rugby player performs approximately 180 activities with 56% lasting less than 10 s [3]. Interestingly, racquet sports are also characterized by high-intensity efforts lasting between 5 and 10 s [4]. Consequently, previous investigators have developed repeated sprint tests to assess players and athletes including a variety of numbers of repetitions (5 to 15) [5,12,13], covered distances (5 to 40 m) [13,14], time and recovery modes [14,15],

and sprint durations (5 to 6 s) [14,15] based on straight line, shuttle run and with light changes of direction in forward sprint [5,6,8,13,14,16].

During team sports activity, acceleration, deceleration, changes of direction and multidirectional displacements in forward, lateral and backward directions are performed continuously throughout the game in response to visual or auditory stimuli [16,17,18]. Consequently, the player is required to change directions with a minimum loss of speed, balance, and/or motor control in reply to a stimulus. These requirements are widely reported in the agility literature. In fact, Sheppard et al. [18,19] defined 'agility as a rapid whole body movement with change of velocity and/or direction in response to a stimulus'. In their analysis of literature on agility, Sheppard et al. [18] mentioned two types of agility: (i) reactive agility in which the change of direction is a reaction to a stimulus soliciting a cognitive and reactive component; and (ii) planned agility in which the change of direction is pre-planned, soliciting a physical component of agility such as leg muscle qualities, power and change of direction speed [18]. In the last decade, the T-test

for agility was put forward as a valid and reliable tool for planned agility assessment. The basis of this test [20] is simply to measure the ability to rapidly change directions and position in the horizontal plane with multidirectional sprint in forward, lateral, and backward directions [18].

The ability to repeatedly produce short, maximal efforts with brief recovery periods and agility skills are two important and decisive fitness requirements for team sports [16,19,21]. Therefore, their improvements and regular monitoring, via physical tests, are crucial, in particular at high levels. However, new tests associating the ability to repeatedly produce short and maximal efforts with brief recovery periods and agility are promoted to reproduce similar effort as the game. Based on the results of time-motion analyses, these protocols have typically involved repeated bouts (≤ 20) of maximal work lasting ≤ 10 s, interspersed with relatively short rest periods (≤ 60 s) [12, 14,16,17], with the ratio ranging from 1:1 to 1:14 [4]. The key performance outcomes derived from such tests are an individual's maximum multidirectional sprint speeds and the ability to resist fatigue and maintain a high-performance level throughout the test [13, 15,17]. In this context, Haj Sassi et al. [22] validated the repeated modified agility T-test (RMAT) in male athletes. The RMAT consists of 10×20 m maximal running where the subject moved forward, laterally and backward (Half T-test) with an approximately 25 s recovery between each shuttle run. The RMAT can be used to evaluate the leg strength and power in intermittent sports where space and distance are short and limited such as volleyball and tennis [22]. However, a more appropriate test based on stop and go and assessing longer distances and bigger spaces is required for games covering wider fields. In this context, the T-test was used in the current study to simulate the significant efforts and distance covered in team sport with large areas/pitches, as well as the wide variety of exercise types and intensities performed during games.

The purpose of this study was therefore to assess the reliability and criterion-related validity of a new repeated sprint T-test (RSTT) that includes short, intense efforts in multidirectional displacements separated by periods of recovery in team players. We hypothesized that the RSTT performances would: i/ provide stable test–retest scores and low minimal detectable change (MDC_{95}), and ii/ show relationships with repeated sprint tests.

MATERIALS AND METHODS

Subjects. Forty-five male team sport (soccer n=22, handball n=12, and rugby n=11) players (age: 20.5 ± 0.5 years; body mass: 75.6 ± 6.9 kg; height: 183.6 ± 4.5 cm) volunteered to participate in this study. Subjects were professional or semi-professional players. They had at least 10 years of practice in their respective sports and were pursuing university studies in Sports Sciences. Their average weekly training volume was ~15 h·wk⁻¹ including various physical activities as part of their university courses, such as ball games, swimming, athletics, gymnastics, combat sports and regular training with their team sport.

Procedures

The present investigation was performed in 5 sessions all separated by 3 days. The first session was dedicated to informing the subject about the experimental procedures, familiarization with tests and anthropometric measurements. RSTT and RSTT re-test, repeated linear sprint (RLS), and repeated sprint with changes of direction (RSCD) were performed in the second, third, fourth, and fifth sessions in a randomized and counter-balanced order. The same distance, number of repetitions and recovery in all repeated sprint tests (RSTT, RLS and RSCD) were applied to assess the effect of the change of direction and multi-directional displacement on performance. All sessions were performed at the same time of the day between 3.00 p.m. and 6.00 p.m. to minimize the effects of diurnal variations on the measured variables. Ambient temperature and relative humidity were: 23±2°C and 62±4%, respectively. Standard verbal encouragement was consistently given for all subjects throughout the tests by the same researcher. The participants were instructed to avoid any strenuous physical activity 24 hours prior to each assessment session. Before testing, subjects warmed up standardly for ten minutes; this was based on jogging, dynamic stretching exercises, and some acceleration at a short distance. After five minutes of recovery, subjects began the test. Timing data were recorded using an electronic timing system (Cell Kit Speed Brower, USA) placed 1.0 m above the ground.

Repeated sprint T-test (RSTT)

The aim of the RSTT is to simulate parts of the real game. This simulation is justified as the RSTT includes short, intense efforts separated by recovery periods between sprints, and secondly, this test contains various displacements in multidirectional modes, i.e. running forward, laterally and backward. The RSTT consisted of 7 maximal repeated executions of the agility T-test with 25 s of passive recovery rest period in between. Within each between-sprints recovery period, subjects tapered down from the sprint just completed and slowly walked back to the next start point and waited for the
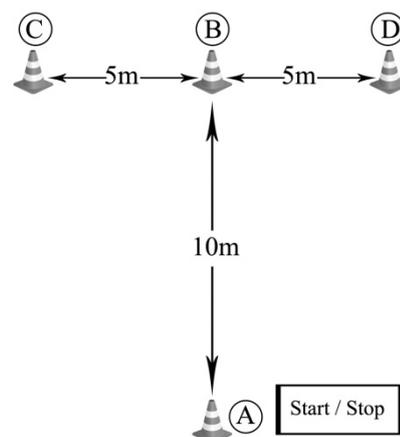

FIG. I. Diagram of T-test.

next audio signal. The performance indices of the RSTT were: best time (BT), total time (TT), and fatigue index (FI), where BT was the best time of seven sprints, TT was the sum time of seven sprints, then FI was calculated as follows [23]: FI = ((TT / (BT × 7)) ×100)-100. The T-test for agility (Figure 1) was selected to construct the RSTT because it is a reliable and valid measurement [20] of the ability to rapidly change directions and speed [18] based on stop-and-go planned agility with multidirectional displacements, such as forward sprinting, left- and right-side shuffling, and backwards run frequently performed in team sports.

Repeated linear sprint (RLS)
The RLS consisted of 7×40 m maximal sprints in a straight direction with 25 s passive recovery in between. In between repetitions, subjects did the same as for the RSTT: slowly walked back to the next start point and waited for the next audio signal. The performance indices of the RLS were BT, TT and FI.

Repeated sprint changes of direction (RSCD)
The RSCD consisted of 7×40 m maximal sprints, including three changes of direction in slalom, as previously described by Baker [2] and validated by Wragg et al. [16], with 25 s of passive recovery in between. Also, in between repetitions, subjects did the same as for the RSTT and RSCD tests. Similarly, the performance indices of the RSCD were BT, TT, and FI.
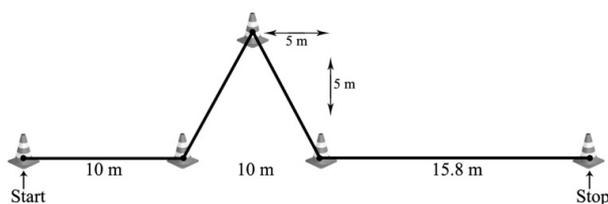

FIG. 1. Diagram of repeated sprint changes of direction.

Statistical analysis
Data are shown as mean ± SD. Normality of distributions was verified using the Kolmogorov-Smirnov test. A one-way repeated measures analysis of variance (ANOVA) was used to assess the difference in sprint time during the seven sprints in the RSTT. When the differences were significant, a Tukey post-hoc test was performed to locate the pair-wise differences. Likewise, ANOVA was also used

to determine the difference between indices of the RSTT, RLS, and RSCD. Systematic bias was investigated using a dependent t-test to evaluate the hypothesis that there was no significant difference between tests and retest sample means performance indices of the RSTT. To assess the meaningfulness of differences between tests and retest performance indices, the effect size (dz) was calculated and interpreted according to Hopkins [24]. To determine the relative reliability of the RSTT, the intra-class correlation coefficient (ICC) was calculated [25]. In order to test the absolute reliability of the RSTT, the standard error of measurement (SEM) [26] was established to reflect within-subject reproducibility for those measures mentioned above. Moreover, the MDC_{95} was established. The MDC reflects the 95% confidence interval (CI) of the difference in score between paired observations, calculated as $MDC_{95} = SEM \sqrt{2} \times 1.96$ [27,28]. Pearson's product moment correlation coefficient (r) associated with the coefficient of determinant (R^2) was used to examine the relationships between the performance indices of the RSTT, RLS, and RSCD. All statistical analyses were conducted using IBM Statistical Package for the Social Sciences (Version 18.0, SPSS for Windows). The level of significance was set at $p < 0.05$.

RESULTS
The performance indices (BT, TT, and FI) in the RSTT, RLS and RSCD are shown in Table 1.

The ANOVA between the performances in seven sprints of the RSTT showed a statistically significant difference (F=3.36, p<0.01). Pairwise comparisons between seven sprints showed that the first sprint was not significantly different from the second sprint (p=0.91). Then the sprint time increased from the third to the seventh sprint (p<0.05).

The BT and TT recorded during the RSTT were higher than the BT and TT recorded during the RLS and the RSCD (F=734.3 and

TABLE 1. Mean ± (SD) performance during the RSTT, the RLS, and the RSCD.

Performance	RSTT	RLS	RSCD
BT (s)	10.3±0.9	4.8±0.6	5.2±0.8
TT (s)	75.3±6.8	35.2±4.6	37.8±6.5
FI (%)	4.1±1.8	4.5±0.9	4.2±1.7

Note: RSTT: Repeated sprint T-test; RLS: repeated linear sprint; RSCD: repeated sprint changes of direction; BT: best time; TT: total time; FI: fatigue index.

TABLE 2. Mean ± (SD) performance characteristics and results of relative reliability of the RSTT (n=45).

Performance	Test	Retest	ICC	dz	SEM	MDC_{95}
BT (s)	10.3±0.9	10.3±0.8	0.97	0.02	0.03	0.09
TT (s)	75.3±6.8	75.2±6.8	0.98	0.01	0.21	0.58
FI (%)	4.1±1.8	4.2 ± 1.8	0.98	0.04	0.12	0.54

Note: ICC: intraclass correlation coefficient; dz: Cohen's d for the paired sample t-test; SEM: standard error of measurement; MDC: minimal detectable change; BT: best time; TT: total time; FI: fatigue index.

TABLE 3. Pearson's product moment correlation between the performance of the RSTT and the other tests (n=45).

Performance		RLS			RSCD		
RSTT		BT (s)	TT (s)	FI (%)	BT (s)	TT (s)	FI (%)
BT (s)	r	0.86**	0.85**	-0.14	0.81**	0.78**	-0.13
	R^2	0.76	0.74	0.01	0.67	0.63	0.02
TT (s)	r	0.89**	0.88**	-0.13	0.82**	0.79**	-0.12
	R^2	0.81	0.78	0.01	0.69	0.64	0.01
FI (%)	r	-0.71*	-0.7*	0.02	-0.56*	-0.54*	0.35
	R^2	0.43	0.47	0.01	0.34	0.31	0.01

Note: RSTT: Repeated sprint T-test; RLS: repeated linear sprint; RSCD: repeated sprint changes of direction; BT: best time; TT: total time; FI: fatigue index; **, * significant correlation between variables at $p < 0.01$ and $p < 0.05$.

624.7, p<0.01; for BT and TT, respectively). No significant difference was observed between the FI for the three tests (F=0.0986, p=0.43).

The dependent t-test performed between test-retest mean scores for the BT, TT and FI showed no significant differences (p=0.17; p=0.64 and p=1.77, respectively). The mean ± SD for the test–retest of the RSTT indices, the ICCs, the effect size (dz), the SEMs and MDC_{95} between the two test sessions are given in Table 2. The dz values were lower than 0.05 for all indices of RSTT. The ICCs were higher than 0.90 for the BT and TT, which suggested a high degree of relative reliability between the test and retest sessions.

Relationships between the performance indices of the RSTT and the other tests are summarized in Table 3. The BT and TT of the RSTT test were significantly correlated with BT and TT of RLS and RSCD tests.

DISCUSSION

The ability to repeatedly make short, maximal efforts with brief recovery periods and agility are two decisive and important fitness requirements for team games. The literature provides several tests designed to assess these qualities separately. The current study was conducted to assess the reliability and criterion-related validity of a new RSTT that includes short and intense agility efforts separated by periods of recovery in team sports. The RSTT appeared to be a reliable and valid measure of the ability to perform intermittent high-intensity agility exercise.

Performance during the seven sprints in the RSTT showed a significant decline. The best times were recorded during the first and the second sprints (10.43±0.92 s vs. 10.40±0.82 s, p=0.91), after which the sprint time increased from the third to the seventh sprint (p<0.05). The increase in sprint time during repeated sprints, i.e. the decreased performance, could be explained by a likely gradual onset of fatigue that is one of the aims of the repeated sprint concept assessment [4,14,15]. The decreased performance, as confirmed by the FI, observed during the RSTT corroborates previous studies investigating repeated sprint ability [5,8,14,23]. In this context, Haj Sassi et al. [22] found the best times in the last sprint in the RMAT, whereas our data showed that the best time occurred

during the first and the second sprints. Despite the similarity of design between the RSTT and RMAT, physiological and physical processes for both tests were clearly different. Also, in determining the criterion validity of the RMAT, Haj Sassi et al. [22] studied the relationship between RMAT performance and peak power and average power during the Wingate test, vertical jumps (i.e. squat jump, countermovement jump and drop jump) and the 5-jump test [22]. The authors concluded that the RMAT test can be used to measure the strength and power of leg muscle, through running with a change of direction [22]. Moreover, the longest distance in the RSTT, based on the regular T-test, could explain, in part, these differences. Indeed, the difference in metabolic cost between the two tests could influence performance, since the RMAT was run over 20 m (half-T test) while the RSTT was run over 40 m. Therefore the present RSTT test is the first to present a mixed repeated sprint ability and agility assessment that follows classical repeated sprint ability test patterns. Indeed, the repeated sprint performances of the RSTT gradually worsened (from the third sprint on), showing the influence of fatigue, which is indeed usually observed during repeated sprint tests. Therefore, we believe that the RSTT test might suit all the requirements of coaches and scientists who aim to assess repeated agility sprinting. Nonetheless, one of the limits of the current study was the lack of metabolic measurements and/or other biomarkers, such as lactate and markers of muscle damage. It would be interesting in the future to assess such variables to better understand the physiological demands of RSTT and to optimize its usefulness in team sports.

The BT and TT recorded during the different repeated sprint tests (RSTT, RSCD and RLS) were significantly different (p<0.01), in spite of the same distance, number of repetitions and recovery in the three tests. That might be caused by the different nature of the effort in these tests in which the subject performed various movements in multidirectional modes, i.e. running forward, laterally and backward. The subjects were required to accelerate and decelerate much more during the RSTT compared to both the RSCD and RLS. In fact, accelerations, and decelerations extend the duration of the effort with a change of direction, resulting in higher energy expenditure than the straight sprint [29]. In the same context, it has been reported that

players spend more energy (20 to 40%) when moving backward or laterally compared to forward runs [30].

To examine the relative reliability of the RSTT, no difference were noted between the sample mean scores of the test and the sample mean scores for the retest of performances indices of the RSTT ($p > 0.05$). The ICC values were 0.97, 0.98 and 0.98 for the BT, TT, and FI, respectively. These values were in the same range of relative reliability value indices reported in previous studies [1,19,20,31]. It was stated that the ICC value of physical and physiological field tests is acceptably reliable if the ICC is over 0.80 and is considered high if it is over 0.90 [6]. The dz values were 0.02, 0.01 and 0.04 for the BT, TT and FI, respectively. The dz was calculated to assess the meaningfulness of differences between test and retest performance indices of the RSTT. According to the modified scale of Hopkins [24], the differences observed between test and retest performance indices of the RSTT were assumed to be trivial. The dz results of the current study agree with the data reported previously [20,31,32], which confirm the relative reliability of the RSTT performance indices.

As recommended by several authors [22,25,27], the absolute reliability of the RSTT test has been analyzed by the SEM. The SEM was not affected by inter-individual variability but was in association with ICC [25]. The difference observed between the two performances indices of the RSTT trials could be related to the error measurement. The small SEM observed in the present study strengthened the reliability of the RSTT.

According to Atkinson and Nevill [27], it is important to use the MDC_{95} as a criterion to determine whether a real change has occurred between test and retest. In the present study, the MDC_{95} values observed for the BT, TT and FI were 0.09 s, 0.58 s and 0.54%, respectively. Therefore, whenever a change in the test-retest RSTT for BT, TT and FI was $\pm$ 0.09 s, $\pm$ 0.58 s and $\pm 0.54\%$, respectively, true changes might have occurred. In practical application [27,28] it is important for administering this test to know that after a training program with male team athletes if changes greater than 0.09 s, 0.58 s and $\pm 0.54\%$, in BT, TT and FI, respectively, occurred, this means that the investigators can be 95% certain that the change in performance reflected real alterations in performance and exceeded measurement error.

In the present study, Pearson product moment correlations showed significant correlations between the BT of the RSTT and the BT of the RLS and the RSCD ($r = 0.86$ and 0.81, $p < 0.01$, respectively). Moreover, significant correlations were also observed between the TT of the RSTT and the TT of the RLS and the RSCD ($r = 0.88$ and $r = 0.79$, $p < 0.01$, respectively). These results have the same significance as previously reported in the literature [22,33,34]. Accordingly, a significant correlation was reported between the total time of 10 sprints of 20 m with 25 s recovery in between and the peak power and average power during the Wingate test with $r = -0.44$ and $r = -0.72$, respectively [22], and likewise between the performance on the squash-specific test and the Baker test (8 sprints $\times$ 40 m) in squash players $r = 0.98$ [34]. On the other hand, Green et al. [33]

reported a low significant correlation between the performance of a specific protocol in rugby including multiple sprints and repeated sprint performance. In the literature, many researchers have reported significant correlations between the different repeated sprints protocols. However, several researchers reported no correlation between repeated sprint protocols; for instance, Meckel et al. [35] compared two repeated run sprint protocols (6×40 m and 12×20 m) and found no correlation. This discrepancy may be related to the great variability in repeated sprint test protocols (distance covered, shuttle or straight sprint, number of repetitions, time and mode of recovery, etc.), which affects the relationship between these protocols.

In the current study, the relationship between TT and BT for the RSTT, RLS and RSCD was highly significant. This result could be the consequence of the same distance, number of repetitions and recovery in the three tests despite the different design of the RSTT which includes various displacements in multidirectional modes (i.e. running forward, laterally and backwards). Generally speaking, it is important to note that the strength and the significance of correlation outcome do not provide any insight into whether the relationship between two variables is causal [27,31]. Therefore, a correlation could confirm a relationship, but not a causal relationship. Hence, the three tests did not strictly measure the same parameters. For this reason, we established the coefficient of determination (R^2). However, the trivial values of R^2 imply that RSTT was correlated with repeated sprints and agility, but with a low causal relationship. This suggested that other physical and probably physiological components were determinants of repeated agility sprints.

CONCLUSIONS

The present study aimed to assess the reliability and the validity of a new repeated agility sprint test that includes short and intense multidirectional intermittent efforts. The results showed that RSTT enabled a good evaluation of players' ability to repeat agility sprints and performances during that test gradually worsened, demonstrating the progressive intervention of fatigue which is generally observed during standard repeated sprint tests. This new test seems, therefore, to be a useful, reliable and valid tool for assessing players' ability to repeat sprints with many changes of directions/agility. It could be routinely used by sports scientists, strength and conditioning practitioners, and sports coaches within an assessment battery of tests for monitoring the training programmes for team sports players.

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