Original Article

Reliability of aerobic and anaerobic field tests in in measuring athletes' performances: A statistical approach on a cohort of 100 subjects

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ABSTRACT

To determine the statistical relationships among different consolidated performance tests (Yo-Yo, jump, sprint and agility), and the Powersprint™ device, an isotonic equipment, usually used to increase the muscular strength of athletes, used here as performance test. One hundred individuals were involved in the tests (16 females and 84 males). Ninety-five subjects were practicing different field sports, whereas 3 female and 2 male subjects were inactive. Gender, height and body mass were recorded. Participants completed the following tests: Squat Jump, Counter Movement Jump, 10 m sprint, 15 m sprint, Change of Direction, Yo-Yo Intermittent Recovery Test level 1 and PowerSprint 3.0™. Results of this experiment highlighted that PowerSprint 3.0™ is positively and significantly correlated with Squat Jump, Counter Movement Jump, 10 m sprint, 15 m sprint, Change of Direction, Yo-Yo Intermittent Recovery Test level 1. Additionally, the principal component analysis, as expected, was able to neatly differentiates between male, female and inactive subjects. The selected tests appeared particularly effective in giving information about athlete performances in soccer. Performances measured with the PowerSprint 3.0™ positively and significantly correlated with jumps, COD, sprint and YYIR1 tests. This is an indication of the possible use of this light, inexpensive and portable instrument for measuring athlete performances and checking the effectiveness of training programs.
Keywords: Agility tests; Athlete performances; Bosco's test; Sprint test; Yo-yo test; Principal component analysis.

INTRODUCTION

The modern sport disciplines, and consequently the athlete performance, have reached an extremely high level of complexity and difficulty. Without scientific and technological support, even the most expert trainer risks failing to grasp and quantify all the complex phenomena that characterize the effects of training and, therefore, the transformations occurring in the athlete's body (Dal Monte and Faina, 1999).

The monitoring of athlete performances is a delicate phase in all sports training, given that the training load, the training schedule, and the physical 'dose' during training strongly depend on the athletes' level of fitness (Akubat et al., 2012). As the performance monitoring on the sport field is a necessary compromise between the accuracy of results and the ease of measurement, numbers of tests have been proposed and some of them are widely used.

Among those most in use internationally, for sports requiring intermittent performances related to the athletes' ability to repeat intense exertion, there are the aerobic and anaerobic Yo-Yo intermittent recovery tests (YYIR1 and YYIR2) (Bangsbo, 1993; Bangsbo et al., 2008), and the anaerobic Bosco's Squat (Sands et al., 2004) and Countermovement Jump tests (Bosco et al., 1983). These tests are often used in a battery of other tests which may include agility tests, such as the Lateral Change of Direction Test (Sheppard and Young, 2006) and linear sprints (Svensson and Drust, 2005).

The importance of relying on tests with high reproducibility of performance was underlined by Hopkins et al. (2001), who observed that tests with poor reliability are unsuitable both for tracking changes in performance between trials and for assessing performance in a single trial. This is why the assessment of the reproducibility of tests is still a matter of concern, and a number of articles has been published comparing the reliability of different aerobic and anaerobic field tests and their usefulness in different sports disciplines (Krustrup et al., 2003; Sands et al., 2004; Sheppard & Young, 2006; Gabbet et al., 2008; Pasquarelli et al., 2010; Lockie et al., 2013; Darrall-Jones, 2016). Another important issue is the correct interpretation of changes in test score interpretation, including the smallest worthwhile change in performance (Hopkins, 2004).

In order to contribute to the debate on this topic, we studied, in a cohort of 100 individuals practising different sports, the statistical relationships among different "classic" performance tests (Yo-Yo test, Bosco's test, sprint and agility tests), and a new test using the PowerSprint™ device. This isotonic equipment, usually used to increase the muscular strength of athletes, has been used here as performance test. This equipment makes it possible to apply resistance to the athlete's movement, corresponding to a load spanning from 6 to 24 kg, neither impairing the sprint nor negatively affecting the spine. This device is a modern evolution of the variable load tow (Kawamori et al., 2014, used to improve the muscular exertion in sports where an enhancement of explosive strength is required.

METHODS

Participants
One hundred individuals were involved in the tests. Sixteen female subjects with a mean age of 21.5 (range 18-27) year., an average height of 164.1 (range 154-177) cm and an average body mass of 56.4 (range 49-69) kg. Seven of them were endomorphs, 7 mesomorphs and 2 ectomorphs. For the 84 male subjects the mean age was 24.3 (range 19-36) year., the average height was 174.2 (range 164-191) cm, the average body mass was 70.6 (range 61-87) kg. Ten of them were endomorphs, 28 mesomorphs and 26 ectomorphs.

Ninety-five subjects were practicing different field sports, whereas 3 female and 2 male subjects were inactive. All participants were fully informed of the experimental procedures before giving their informed consent to participate. All participants underwent a 10 m warm up session before starting the tests.

Measures
Yo-Yo test
The Yo-Yo intermittent recovery level 1 (YYIR1) was carried out according to Krustrup et al. (2003). All the participants were accustomed to the test before starting the performance measurement. Briefly, the test was carried out on field and consisted of repeated 2x20m runs back and forth along lines indicate by cones marking the starting, turning, and finishing points. An audio beep marked the required increase in speed. Between each running bout, the participants had a 10 s jogging rest period (2x5 m). When the athlete twice has failed to reach the finishing line in time, the number of bouts covered was recorded and the test stopped. The results were expressed as speed levels according to Castagna et al. 2006.

Jump tests
Squat and countermovement jump tests were performed according to Bosco et al. (1983). For both tests the scores were recorded using a mat (Chronojump, Barcelona, Spain) (De Blas et al., 2012) measuring the athlete's flying time. The following formula [equation (1)] was used to express the results:

$$\text{Jump Height} = 4.9 \cdot (0.5 \cdot \text{Flying Time})^2 \qquad\qquad \text{Equation (1)}$$

Sprint test
The athletes put a foot behind a starting line, took a stationary position, with no rocking movements, and then sprinted over distances of 10 and 15m. The athletes' performance were recorded by photo-cells (Witty Wireless Training Timer, Microgate, Bolzano, Italy), with a precision of 0.01s, placed at the starting line, at 10m and 15m.

Agility test
A classical Lateral Change of Direction Test (COD) was carried out according to Sheppard and Young (2006). The athletes' performance measurement was carried out by using the Witty Wireless Training Timer device (Microgate, Bolzano, Italy).

PowerSprint 3.0™
This isotonic instrument is aimed at reproducing on the field a training methodology usually carried out indoor using heavy and bulky machinery. The PowerSprint 3.0™ (Sport Spin Up, Milan, Italy) is a light and compact device measuring 26x26x26 cm and weighing 12kg. It comes with a 18.5m cable connected by a carabineer to a wearable ergonomic belt. The device is fixed to a pole (or to any other suitable fixing point) and the belt is worn by the athlete, who performs series of 10m sprint tests. The device applies a resistance to the athlete's movement corresponding to a variable load adjustable at 6 kg, 12 kg, 18 kg and 24 kg. (Figure 1). The Powersprint 3.0™ has a built-in computer that collect data by means of a) a tachometer that measures speed expressed in $m \cdot s^{-1}$ over a 10 m sprint, b) a dynamometer that measures in N the force developed by the athlete over the same 10 m sprint. The computer also calculates the W produced by the athlete during the test, as derivative physical quantity, by multiplying force by speed using the following conversion factor: 6.118 $kg \cdot m \cdot min^{-1} = 1$ W. This device, new on the market, is gaining popularity in Italy as training accessory in sports where the improvement of explosive strength is required. Considering that this device allows the measurement of athlete's speed, force and W produced during exertion, it was used here as performance test.

Statistical analysis

All the tests were performed in triplicate, save for the YYIR1 and PowerSprint 3.0™ tests. Descriptive statistics were calculated as shown in Table 1. The relationship between various jumping, sprinting, CODs, YYIR1 and PowerSprint 3.0™ tests was calculated using Pearson's method with statistical significance set at p-value < 0.05. The results of sprint and agility tests were expressed as 1/x, in order to take into account that the best performances are those with the lowest scores. Variables measured through different units were autoscaled prior any further statistical elaboration. In autoscaling process data were firstly mean centered and then divided by the standard deviation. Thus, scaled variable results in mean and variance values of 0 and 1, respectively. Principal Component Analysis (PCA) was performed on such scaled variable using Statgraphics 18®Centurion statistical software package.

Table 1. Descriptive statistics, loading and component weights

Descriptive statistics	SQJ (cm)	CMJ (cm)	COD (s)	10 m (s)	15 m (s)	YYR1 (speed level*)	PowerSprint 3.0™ (W)
Number of tests	300*	300*	300*	300*	300*	100**	100**
Mean	28.34	31.24	5.643	1.929	2.461	14.66	1172
Standard deviation	5.25	5.09	0.517	0.192	0.261	1.48	231
Coeff. of variation %	18.5	16.3	9.2	9.9	10.6	10.1	19.7
95% Confidence Interval	27.74-28.93	30.66-31.81	5.585-5.702	1.907-1.951	2.431-2.490	30.66-31.81	1127-1218
Minimum	11.91	15.89	4.87	1.66	2.09	11.1	570
Maximum	41.16	44.19	7.36	2.69	3.24	17.4	1511
PCA- Component Weights							
PC1	**0.34**	**0.32**	**0.38**	**0.37**	**0.37**	**0.34**	**0.36**
PC2	**-0.58**	**-0.65**	0.18	0.18	0.24	0.19	0.06

SQJ = Squat Jump; CMJ = Counter Movement Jump; 10 m = 10 m sprint; 15 m = 15 m sprint; COD = Change of Direction; YYIR1 = Yo Yo Intermittent Recovery Test level 1; PowerSprint 3.0™ see text for explanation; PCA = Principal Component Analysis.
*[a]The speed level is expressed according to Castagna et al 2006; * = 3 repetitions; ** = 1 repetition.*

Table 2. Pearson's correlation matrix

	YYIR1	SQJ	CMJ	10 m	15 m	COD	PowerSprint 3.0™
YYIR1							
SQJ	0.66						
CMJ	0.59	0.94					
10 m	0.76	0.72	0.68				
15 m	0.75	0.7	0.63	0.93			
COD	0.76	0.72	0.69	0.91	0.91		
PowerSprint 3.0™	0.78	0.76	0.69	0.79	0.82	0.87	

All coefficients are significant at p < 0.05. In bracket the units of measure YYIR1 = Yo Yo Intermittent Recovery Test level 1; SQJ = Squat Jump; CMJ = Counter Movement Jump; 10 m = 10 m sprint; 15 m = 15 m sprint; COD = Change of Direction; PowerSprint 3.0™ see text for explanation.

RESULTS AND DISCUSSION

Pearson's correlation reported in Table 2 highlights that PowerSprint 3.0™ is positively and significantly correlated ($p < 0.05$) with YYIR1 (0.78), Bosco's test (0.69 and 0.76), the sprint (0.79 and 0.82) and agility (0.76) tests. Also, YYIR1 and Bosco's tests were found to be positively correlated to each other. According to Salaj and Markovic (2011), these correlations span from moderate to high. Even though it is always difficult to compare results of different studies, as a significant bias could derive from different test characteristics and the different population to which the tests are applied (Chaouachi et al., 2012; Brughelli et al., 2008), it is worth noting that contradicting results are available in literature on the correlations between aerobic, anaerobic and agility tests. Soslu et al. (2016), studying 23 male professional basketball players, found a weak, but positive, correlation between Bosco's tests and the linear sprint tests. On the contrary, Bakers and Nance (1999), investigating the relationship between strength and power in rugby players found a strong positive correlation between maximum strength and maximum power but no relation was reported between strength measures and 10 or 40m sprint performances. Continuing with rugby players, Cronin and Hansen (2005) found a negative correlation among 5, 10 and 30m speed tests and countermovement jump height. Pasquarelli et al. (2010), studying 24 soccer players in the under-17 category, found that Bangsbo Sprint Test were moderately related to agility test, Bosco's test and the capacity of intermittent specific endurance (YYIR2). Salaj and Marcovic (2011), using a Pearson correlation matrix, found that Squat Jump and Countermovement Jump tests were logically positively correlated to sprint tests (5, 10 and 20m) and the 20 yards shuttle run (Y20), which, were positively correlated to each other. Yanci et al. (2014), examining 39 professional soccer players, found negative or no correlations among 9 different kinds of vertical and horizontal jumps and 3 different change of direction ability tests, but significant correlation, even though non-always strong, among vertical and horizontal jumps and 5, 10 and 15 sprint tests was recorded. However, the relationships between different kinds of jumps, sprints, agility tests and shuttle runs still remain unclear. Our data shown a strong statistical relationship between aerobic and anaerobic tests carried out in this work.

As we observed moderate to strong positive correlations among Bosco's tests and the aerobic CODs, sprint and PowerSprint 3.0™ tests, we partially agree with Salaj and Markovic (2011), who affirmed that "jumping, sprinting, and CODs performance should be both treated and tested as separate motor abilities". In the same line are Cronin and Hansen (2005), who observed that acyclic vertical-type movements, such squat and vertical jumping, cannot be used in predicting performances in cyclic and horizontal movements. These motor abilities are indeed different, as they involve different muscular movement, but in our study each of them was shown to be predictive of performances in all the tests here considered. Our results are in agreement with those of Wisløff et al. (2004) and Comfort et al. (2014), who both found strong correlation between maximal strength, sprinting, and jumping performances.

Our results seem to be also in agreement with Markovic et al. (2007), who observed that plyometric training is commonly acknowledged, by both researchers and practitioners, as method of choice for training athlete's explosive leg power, together with sprint running. Despite the different muscle functions involved and the training effect produced by plyometric and running sprint performances, they both appear to be able to enhance muscle power capabilities. Our data to point out a high correlation between these two different training strategies, as both the plyometric and sprint scores of athletes involved in our study seems to be predictive of leg power and dynamic athletic performances.

Principal component 1 (PC1) explained 79.6% of variance, whereas component 2 (PC2) explained 8.8%, for a total of 88.4%. Figure 1 shows the results for all the 100 participants in our study concerning the different tests. The results of this analysis correctly and neatly differentiate between male, female and inactive

subjects. Sixty-three per cent of the male subjects are located in the PC1 positive portion of the scores plot, regardless of the sport practiced, whereas all the female subjects are located in the PC1 negative portion of the scores plot, without a clear distinction between the practiced sport. As shown in Table 1, loadings weigh in PC1 are similar and are all characterized by high values (> 0.3). These variables have approximately the same relevance and accurately describe the performances of athlete located in the positive portion of the scores plot. Additionally, in PC1 positive quarter of the plot are the 74% of soccer athletes, highlighting the particular efficacy of the selected tests in giving information about athlete performances in this sport.
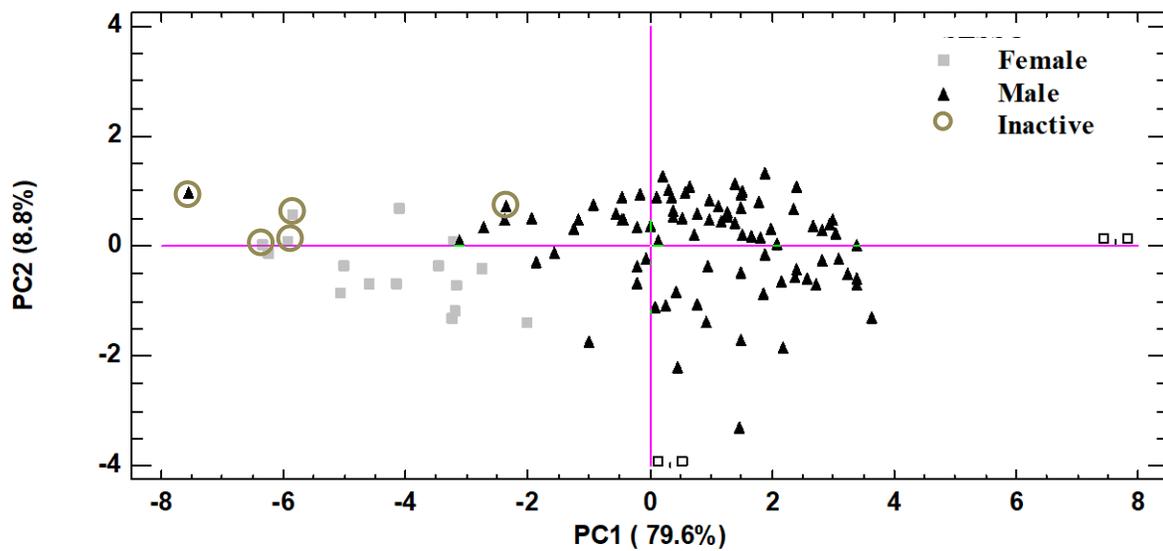

Figure 1. Scores plot of Principal Component Analysis

CONCLUSIONS

Performance indicators, and the correlation among them, are widely used as a guide for organising training sessions and as a tool for checking whether the training program is promoting the required physical capacities of the athletes (Spigolon, 2017). Such indicators are frequently used on empirical basis by practitioners, as the statistical correlation among them available in the scientific literature still gives contradictory results. In this work, we obtained positive correlations, from moderate to strong, for all the tests performed. This contributes to a better understanding of the correlation among aerobic, anaerobic and agility tests here studied, as this matter appears to be still under debate in the scientific literature. The aim of this work is to support sporting practitioners by establishing a statistical correlation between battery of tests suitable both for tracking changes in performance between trials and for assessing performance in a single trial.

Tests aimed at measuring neuromuscular functions (jump tests and sprint performances together with isokinetic and isoinertial dynamometry) are widely used in the sport environment thanks to the simplicity of administration and the minimal amount of additional fatigue induced (Halson, 2014). The equipment used for most of them includes contact mats, portable force platforms, photocells and easy-to-use laser devices. As isokinetic and isoinertial dynamometry are, instead, heavy, expensive and often unmovable equipment, their use in the field practice is limited. It is interesting here to note that performances measured with the PowerSprint 3.0™ positively and significantly correlated with jumps, COD, sprint and YYIR1 tests. This is an

indication of the possible use of this light, inexpensive and portable instrument for measuring athlete performances and checking the effectiveness of training programs.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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