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Squash-specific exercise test for elite squash players: Development and validity

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ABSTRACT

The aim of this study was (1) to develop a squash-specific exercise test (SSET) that simulates relevant physical and energetic demands especially necessary in elite squash and that can be used as a exercise test in the field, and (2) to assess its face and convergent validity. To develop a squash-specific exercise test for elite players a step-by-step procedure was applied. To assess face and convergent validity, a cross-sectional study based on a within-subject design was conducted among six healthy female elite squash players. Face validity was evaluated by comparing (Pearson correlation coefficient) the SSET outcome ($m.sec^{-1}$) and the participants ranking from 1 to 6 accordingly to the Women's international squash player association (WISPA). Convergent validity was evaluated by exploring the associations (Pearson correlation coefficient) between the SSET and a maximal treadmill running test for maximum oxygen uptake (VO2max), maximum heart rate (HRmax) and maximum blood lactate (La+) outcomes. The SSET was developed as an exercise test with movement patterns common in squash, consisting of 4-6 stages of each 5-10 runs of each 39.72 m with speed increasing at each stage and a short rest between each run (10 s) and each stage (30 s). Outcome of the SSET is the speed the subject achieved at the last completed run. Subjects reached their maximum running speed within a total testing time of 20 minutes. Pearson correlation coefficient calculated with the SSEToutcomes and WISPA ranking was -0.78 ($p>.05$). Pearson correlation coefficient between the SSETand the maximal treadmill running test outcomes was 0.90 ($p<.05$) for VO2max, 0.99 ($p<.01$) for HRmax, and -0.09 ($p>.05$) for La+. We developed a squash-specific exercise test for elite squash players. Face validity of the SSET with the WISPA ranking was found to be good, while convergent validity between the SSET and a maximal treadmill running test was found to be good for VO2max and HRmax, and poor for La+.

INTRODUCTION

In elite sport, coaches and applied sport scientists are constantly seeking and applying innovative training methods and optimal strategies in order to have their athletes achieve high performances. One of these strategies is to monitor and evaluate the physical performance of their athletes. Physical performance testing should focus on specific variable measures related to performance in the sport of interest.[1] The more specific the test, the more likely it provides valuable information for evaluating training programs and physical improvement.[1] Therefore, specific field tests have been developed in several sport disciplines, for example in professional football (soccer) and elite badminton.[1,2]

Squash is a sport discipline quite similar to tennis and badminton: it requires the repetition of several activities (sprinting, twisting/turning) in combination with an excellent coordination.[2] Squash is a fast game in which several essential physical skills are needed to perform on elite level, especially cardio- respiratory fitness, muscle endurance, muscle strength, muscle speed, flexibility, and agility.[2] Squash at elite level requires a combination of both aerobic and anaerobic systems. Involvement of these energetic systems depends on the nature and duration of the game and rallies. On average, a squash rally can last between 1,5 seconds and several minutes; however, periods of 6 to 20 seconds are the most common.[2,3] A continuous exercise test for measuring aerobic capacity seems therefore not squash-specific enough and is possibly not predictive for performance in competition. At the time of the present study, no suitable squash-specific field test relying on minimal equipment and being easy to set up was available for coaches or sport scientists in the Netherlands. Therefore, a squash-specific exercise test for elite players in which relevant physical and energetic demands of squash are represented, should be developed and evaluated.[2,3] As for any instrument applied in any context for any purpose, such a squash-specific exercise test for elite players should be valid.[4,5]

Validity is the extend that an instrument or test truly measures what it purposely intends to measures.[4,5] The assessment of validity is not straightforward because of its plural types and definitions.[4,5] Face validity refers to the appropriateness of the purpose of an instrument or test, in other words whether it appears to measure what it is supposed to measure (adequate simulation). Convergent validity measures how the evaluated test relates to another instrument that is assumed to reflect an associated concept, with outcomes of both tests or instruments expected to correlate moderately with each other.[4,5]

Considering the need of a squash-specific exercise test for elite squash, and with regard to the aforementioned validity considerations, the aim of this study was two-fold: (1) to develop a squash-specific exercise test that simulates relevant physical and energetic demands especially necessary in elite squash and that can be used as an exercise test in the field, and (2) to assess its face and convergent validity.

MATERIALS AND METHODS

Development of the squash-specific exercise test

In order to develop a squash-specific exercise test (SSET) that is useful especially for elite but also for amateur squash players, the following steps were conducted:
- *Step 1:* Retrieving the exposure to squash related activities from literature,[4,7-9] describing the duration, frequency and intensity of the squash related activities (rallies, movements, rest) and physiological parameters (heart rate and lactate level) of the players;
- *Step 2:* Setting movement patterns and run distances in accordance to the literature,[4,7-9] but also consulting elite squash expert(s) in order to empower validity concerns;
- *Step 3:* Setting the duration of the runs in order to reach a steady-state at each stage;
- *Step 4:* Setting the intensity *i.e.* speed of the runs in such a way that the increase in speed was constant and the same for all stages;
- *Step 5:* Setting the rest between the runs and stages in analogy to the Yo-Yo intermittent recovery test, that means using short recovery breaks that concur with squash match demands;[10] in addition, both practical and feasibility issues (i.e. allow for lactate measurements between stages) are taken into account;
- *Step 6:* Setting the total duration of the test in such a way that athletes could reach their maximum, within a total testing time of about 15 to 20 minutes;
- *Step 7:* Choosing a relevant outcome for the test with regard to the intensity related to the run and the stage the test was stopped.

Validity design

A cross-sectional within-subject design was conducted to assess face and convergent validity.

Participants

Six female elite squash players, all highly trained and free of any musculoskeletal disorders, participated in this study. Three of these participants were ranked top 50 on the Women's international squash player association (WISPA) ranking list from December 2008, from which two of them won a gold medal at the European Team Squash championship 2010 in France. The participants' mean age (standard deviation; range) was 31 years (8; 23–45 years), their mean height was 170 cm (8.3; 155–179 cm), and their mean body weight was 59.5 kg (5.7; 53–67 kg). All participants had been active in elite squash for many years, involving a large number of intensive trainings and matches per week.

Face validity

Face validity was evaluated by assessing the association between the SSET outcomes and the ranking of the participants from 1 to 6 in accordance to WISPA list (December 2008).

Convergent validity

Convergent validity was evaluated by comparing relevant outcomes measured during the SSET and during a maximal treadmill running test. During both assessments, the following outcomes were measured: maximum oxygen uptake (VO2max), maximum heart rate (HRmax) and maximum blood lactate (La+). VO2max was measured by using a breath-by-breath portable gas analyzer (Cortex Vmax ST; Leipzig, Germany), with a gas analyzer calibrated before and after each trial with a 3-L syringe (Hans Rudolph Inc., Dallas, TX) and a known gas concentration (16.0% O2 and 5.0% CO2). HRmax was measured by a hest belt (Polar Electro, Kempele, Finland). La+ was measured by using blood samples taken from the ear lobe and analyzed with the Lactate Pro (LT-710; Arkray, Japan) portable analyzer.

Procedures

All participants were fully informed of the aim and procedures of the study. After signing statements of informed consent, participants were assessed on body height, body mass en percentage body fat. Then, each participant was assessed on both SSET and a maximal treadmill running test, using a time interval of minimal 2 weeks that concurs with recovery guidelines following maximum efforts.[11] This study was performed in accordance with the Helsinki Declaration (1964) and official ethical approval of a medical ethical committee was not needed because our study involved healthy participants performing activities being part of the participants' usual sports' and competition activities.

Statistical analyses

Descriptive statistics (*i.e.*, means, standard deviations and ranges) of the participants were calculated for the study outcomes (SSET, VO2max, HRmax and La+). Face validity was evaluated by correlating the SET outcomes ($m.s^{-1}$) and the ranking on the WISPA using a Pearson correlation coefficient.[5,12] Correlations greater than 0.60 were considered good, between 0.30 and 0.60 were moderate, and less than 0.30 were poor.[5,12] Convergent validity was evaluated by calculating Pearson correlation coefficients in order to explore the associations between the SSET and maximal treadmill running test for VO2max, HRmax and La+.[5,12] Correlations greater than 0.60 were considered good, between 0.30 and 0.60 were moderate, and less than 0.30 were poor.[5,12]. All data analyses were performed using the statistical analysis software SPSS 19.0 for Windows.

RESULTS

Development and content of the squash-specific exercise test

- *Step 1:* the information on exposure to squash related activities in terms of duration, frequency and intensity was retrieved from literature and is available upon request;
- *Step 2:* movement patterns and run distances are presented in figure 1. In the SSET, the subject moved from a central base to one of six targets located around the court, in the following order: right side/behind; right side/centre; right side/front; left side/behind; left side/centre; left side/front. The subject was instructed to perform a stroke with the racket when arriving at the target;
- *Step 3:* duration of the stages and the number of runs is presented in table 1. Each intensity level (a stage) was 3:30-4:00 minutes, consisting of 5-10 runs of each 39.72m;
- *Step 4:* intensity *i.e.* speed ($m.s^{-1}$) of the runs and stages is presented in table 1. Movement velocities were controlled by auditive automated feedback;
- *Step 5:* rest between the different runs within a stage was set at 10 s, while the rest between two stages was set at 30 s;
- *Step 6:* the SSET consisted of 15 stages in total. The aim of the SSET was that the subject performs 4-6 stages, leading to a total testing time of about 15 to 20 minutes. Therefore, depending on the physical capacity of the subject, the initial stage was chosen. It was found reasonable to have amateur squash players begin with stage 2, elite female squash players with stage 5, and elite male squash players with stage 6. The stage before the first stage was performed as warming-up. The test ended when the player stopped voluntarily or failed to reach the target in time three times in a row;
- *Step 7:* the maximal performance outcome of the SSET was the maximal speed ($m.s^{-1}$) the subject achieved at the last completed run, adding for each run the proportional rate speed of the run to the last completed stage (for example: stage 10 run 4: 4/8 x [2.75-2.58] + 2.58 = 2.67 $m.s^{-1}$).

Face validity

Outcomes of the SSETand ranking on the WISPA per participant, and groups mean and standard deviation are presented in table 2. Pearson correlation coefficient was -0.78 ($p>.05$), showing a good association between SSETand WISPA ranking and a good level of face validity.

Convergent validity

Mean and standard deviation of VO2max, HRmax, La+ and RPE outcomes measured during the SSET and the maximal treadmill running test are presented in table 3. Pearson correlation coefficient between outcomes during the SSETand the maximal treadmill running test was 0.90 ($p<.05$) for VO2max, 0.99 ($p<.01$) for HRmax, and -0.09

($p>.05$) for La+. Consequently, convergent validity between the SSETand a maximal treadmill running test was found to be good for VO2max and HRmax, and poor for La+.

DISCUSSION

The aim of this study was to develop a squash-specific exercise test that simulates relevant physical and energetic demands especially necessary in elite squash and to assess its face and convergent validity. Based on information about exposure to squash related activities retrieved from literature, a squash-specific exercise test (SSET) was developed. Among elite squash athletes we assessed face and convergent validity. Face validity between the SSET outcome ($m.s^{-1}$) and the WISPA ranking was found to be good. Convergent validity between the SSET and a maximal treadmill running test was found to be good for VO2max and HRmax, and poor for La+.

With regard to potential methodological considerations, one limitation of our study is the small sample size of our study group. However, the difficulty to conduct experimental researches in large groups of elite athletes is well known: elite athletes and their staff (technical and medical) members are not easily open to empirical research, and eventual experimental procedures must fit both training and competition planification and scheme burden. Nevertheless, our study group is a good representation of the Dutch elite female athletes from this sport discipline as the number of potential participants *i.e.* elite squash players, is rather limited in the Netherlands. This aspect has had also some consequences for our experimental procedures. As reproducibility is, aside validity and responsiveness, an important clinimetric property when it comes to the measurement's quality of an instrument or a test, a within-subjects design based on repeated measures would have been suitable to evaluate the SSET reproducibility.[5,6] Unfortunately, assessing all participants twice within few days on the SSET was not feasible and therefore, reproducibility of the SSET could not be explored in our study. Another methodological issue that can be discussed concerns our choice to evaluate face and convergent validity of the SSET. The assessment of validity is not straightforward because of its plural types and definitions.[5,6,12] Three types of validity are generally considered, among which criterion-related (concurrent and predictive) validity can be seen as the most powerful and relevant one.[5,6,12] However, in order to assess criterion-related validity, an existing instrument measuring the same concept (or partially the same concept) of the evaluated test (SSET) and showing evidence of both reproducibility and validity, so called gold standard, needs to be available.[5,6,12] With regard to the SSET developed in our study, no similar squash field test was available or seen as a gold standard, and therefore, the assessment of both face and convergent validity seems legitimate as a practical and relevant solution.

In either racket or ball sports such as tennis, squash or football, sport achievements are relying on technical, physical, mental and tactical abilities. Physical and physiological testing focussed during many years exclusively on either non-specific or laboratory practices. However, scientists and coaches have been emphasising since a quarter of a century the importance of the assessment of athletes as specific and practical as possible. For squash players, Steininger and Wodick (1987) developed a field test that was performed in a squash court, using six light bulbs connected to a program device causing individual bulbs to light up in a given sequence.[13] The players were instructed to react to the flashes by running towards and striking balloons, test consisting of series of 3 min periods of exercise with an increased number of runs per unit of time.[13] Twenty years later, Girard et al. (2007) developed a squash specific graded test which subjects repeated displacements that simulated the game of squash, in which each intensity level (a stage) consisted in two bouts of nine shuttle runs.[14] Some aspects from our developed SSET are analogously to both aforementioned existing squash tests, for instance the movement patterns. However, the most notable innovation of the SSET relies in the duration of rest between each runs, which simulate optimally the squash match demands. Furthermore, developed analogously to the widely used Yo-Yo intermittent recovery test, the SSET requires minimal equipment, and is functional and simple to set up and conduct, issues that are particularly relevant in sport testing. At last, the SSET was assessed with regard to its measurement properties i.e. validity, which is necessary for any field test being developed for any purpose.

Table 1: Number, duration and intensity of the different stages and runs of the squash-specific exercise test (SSET).

Stage	1 WUA	2	3	4	5 WUF	6 WUM	7	8	9	10	11	12	13	14	15
Runs	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10
Speed ($m.s^{-1}$)*	1.18	1.35	1.53	1.70	1.88	2.06	2.22	2.40	2.58	2.75	2.93	3.11	3.28	3.47	3.64
Duration of stage (s)	209	187	206	190	177	195	185	176	193	185	178	195	189	183	199

*WUA, warming-up amateur; WUF, warming-up female; WUM, warming-up male; *, speed of the completed stage after all runs*

Figure 1: Movement patterns and run distances of the squash-specific exercise test (SSET).

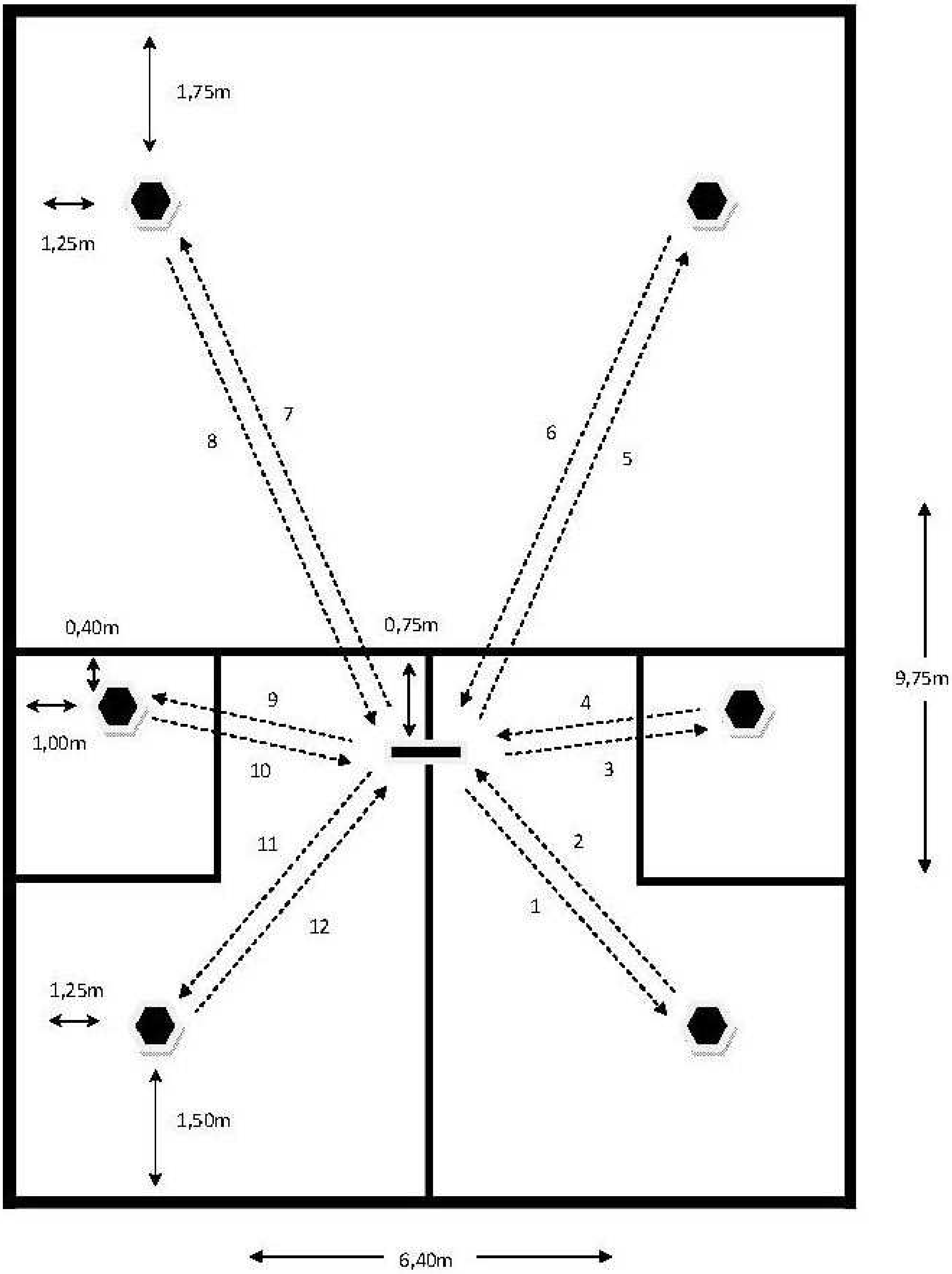

Table 2: WISPA ranking and squash-specific exercise test (SSET) outcomes

Subject	SSET ($m.s^{-1}$)	Ranking
1	2.35	6
2	2.71	5
3	2.84	3
4	2.71	2
5	2.64	4
6	2.84	1

Table 3: Correlation between the squash-specific exercise test (SSET) and the maximal treadmill running test for VO2max, HRmax and La+.

	VO_{2max}		HR_{max}		La^+	
	SSET	TM	SSET	TM	SSET	TM
Mean	48.9	49,1	187	185	7,6	7,9
SD	5,3	5,2	16	14	1,0	1,9
Pearson r	0.90*		0.99**		-0.09	

*TM, maximal treadmill running test; VO_{2max} = maximal oxygen uptake (mL•kg−1•min−1); HR_{max} = maximal heart rate (beats•min-1); La^+ = blood lactate concentration (mmol•L^{-1}); SD, standard deviation; * $p < .05$; ** $p < .01$.*

CONCLUSION

The SSET, a squash-specific exercise test for elite players, was developed and found to have a good level of validity in elite female squash athletes when compared to WISPA ranking and to maximal treadmill running test for several physiological parameters. Requiring minimal equipment, and being more functional and simple to set up and conduct, such a field test should have the preference of coaches and scientists over laboratory testing in order to assess and monitor the physical fitness of players. Reproducibility of the SSET should be evaluated and standard error of measurement should be calculated in order to get an insight in its sensitivity to change. Furthermore, validity of the SSET should be assessed in male elite squash players, as well as in amateur squash players.

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