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Research article

Reactive Agility Performance in Handball; Development and Evaluation of a Sport-Specific Measurement Protocol

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Abstract
There is no current study that examined sport-specific tests of reactive-agility and change-of-direction-speed (CODS) to replicate real-sport environment in handball (team-handball). This investigation evaluated the reliability and validity of two novel tests designed to assess reactive-agility and CODS of handball players. Participants were female (25.14 ± 3.71 years of age; 1.77 ± 0.09 m and 74.1 ± 6.1 kg) and male handball players (26.9 ± 4.1 years of age; 1.90 ± 0.09 m and 93.90±4.6 kg). Variables included body height, body mass, body mass index, broad jump, 5-m sprint, CODS and reactive-agility tests. Results showed satisfactory reliability for reactive-agility-test and CODS-test (ICC of 0.85-0.93, and CV of 2.4-4.8%). The reactive-agility and CODS shared less than 20% of the common variance. The calculated index of perceptual and reactive capacity (P&RC; ratio between reactive-agility- and CODS-performance) is found to be valid measure in defining true-game reactive-agility performance in handball in both genders. Therefore, the handball athletes' P&RC should be used in the evaluation of real-game reactive-agility performance. Future studies should explore other sport-specific reactive-agility tests and factors associated to such performance in sports involving agile maneuvers.

Key words: Change of direction speed, stop-and-go agility, reliability, ecological validity, team-handball

Introduction

Agility is defined as a rapid whole-body movement with changes of velocity or direction in response to a stimulus. It is an important motor ability in sports involving multi-directional changes of direction such as rugby, football, tennis, basketball, handball, etc. (Chatzopoulos et al., 2014; Milanovic et al., 2013). It is common that agility and change-of-direction-speed (CODS) are used interchangeably in the sport literature (Delextrat et al., 2015; Sekulic et al., 2013). However, in real-game situations, a change of direction is often executed in response to unpredictable visual stimuli (e.g., opponent, teammate, ball, etc.), and agile maneuvers may not be explicitly pre-planned (Gabbett et al., 2008; Henry et al., 2011). Therefore, a significant proportion of real-sport-agility depends on quick and accurate responses to stimuli specific to sport environments. To make a clear distinction from pre-planned agility (i.e. CODS) the term "reactive-agility" is commonly used to explain non-planned agility in sports (Scanlan et al., 2014; Sheppard et al., 2006; Young and Willey, 2010).

According to studies that identified different types of CODS performance (lateral, zig-zag, forward-backward running, etc.), the concept of different types of reactive-agility performances is also needed (Sekulic et al., 2013). With sports such as rugby, football/soccer, reactive-agility mostly consists of non-stop running scenarios (i.e. zig-zag running), whereas in other sports (i.e. tennis, handball, basketball) athletes often perform stop-and-go reactive-agility patterns. Recently, testing protocols based on stop-and-go reactive agility were designed and tested for reliability and validity (Sekulic et al., 2014), and results showed (i) high reliability of newly constructed CODS and stop-and-go reactive-agility protocols, and (ii) good validity of the reactive-agility-measurement in discriminating the most- from least-agile athletes of both genders. Differences between CODS and reactive-agility ranged from 10-20%. Finally, the ratio between one's achievement in reactive- agility and CODS was proposed as an indicator of perceptual-and-reactive-capacities (P&RC) of athletes. Namely, the closer the reactive-agility- to CODS-achievement, the closer the athlete to their optimal agility.

Handball (i.e. team-handball) involves multidirectional changes of direction (Massuca et al., 2014). Athletes often perform stop-and-go changes of direction in a response to unpredictable stimuli (ball, opponent, etc.) over a relatively small court (Karcher and Buchheit, 2014). Consequently, previous studies identified agility as one of the most important determinants of successful play in handball (Cavala and Katic, 2010; Vieira et al., 2013; Wagner et al., 2014). However, to the best of our knowledge, all investigations done on handball athletes investigated CODS, and not reactive-agility performance (Cavala and Katic, 2010; Iacono et al., 2014; Vieira et al., 2013). Although CODS is an important quality in handball (mainly in offense), in defense reactive-agility is almost exclusively challenged. Most specifically, defensive players have to quickly respond to opponents' actions, and therefore, agility performance cannot be pre-planned.

Previous studies noted the importance of sport-specific tests in testing reactive-agility to replicate real-sport environments (Gabbett and Benton, 2009; Morland et al., 2013; Sekulic et al., 2014). Having this in mind, we have developed a novel reactive agility test that would be appropriate in defining true game reactive-agility for handball athletes. Therefore, the aim of the present study was to evaluate the reliability and validity of the novel test when used to assess reactive agility of handball players. With regard to validity issue, we hypothesized that players whose reactive-agility is more challenged during the

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game (i.e. defensive players; see later for more details) will outperform those who are not frequently in-volved in reactive-agility-tasks (i.e. offensive players).

Methods

Participants

Participants in this study were female (n = 23; 25.14 ± 3.71 years of age; 1.77 ± 0.09 m and 74.1 ± 6.1 kg) and male handball players (n = 26; 26.9 ± 4.2 years of age; 1.90 ± 0.09 m and 93.9 ± 4.6 kg). All participants were members of teams that competed in the highest League of the National Championship (2013-2014 season). Only participants who had no injury and/or illness for 30 days before the experiment were included in this investigation (based on a health history questionnaire completed prior to testing). The sample was divided into two groups: offensive-players (14 and 13 in males and females, respectively), and defensive-players (12 and 10 in males and females, respectively). The coaches of tested teams were asked to separate their players in specified groups. Goalkeepers were not included in the study. Every participant was fully informed about the nature and demands of the study as well as its potential risks. The study was approved by the corresponding author's Institutional Ethical Board. Accordingly, written information and oral instructions were given to each participant before testing, and all of the participants gave oral consent to participate.

Variables and testing

Variables included body height, body mass, broad jump, 5-m sprint , and handball-specific tests of non-reactive agility (CODS) and reactive agility (reactive-agility). Body height and body mass were assessed using a Seca stadiometer and weighing scales (Seca Instruments Ltd., Hamburg, Germany).

The broad-jump and 5-m sprint test were used to compare the overall training status of the offensive and defensive athletes. These procedures are explained in detail elsewhere (Sekulic et al., 2013).

The handball-specific CODS test and its complementary test of reactive-agility were theoretically designed through consultations with high-level athletes and renowned strength and conditioning experts from handball, including coaches from teams of the highest competitive rank. For the measurement we used some equipment previously validated and based on the ATMEL microcontroller (model AT89C51RE2; ATMEL Corp, San Jose, CA) (Sekulic et al., 2014).

In this study we evaluated participants' results in CODS, reactive-agility, and P&RC index (i.e. ratio between participant's achievement in CODS and reactive-agility) as mentioned previously (Sekulic et al., 2014).

The reactive-agility test was performed on the testing field presented in Figure 1. Athletes began running from the start line when ready. Timing began as participants crossed the infrared (IR) beam. As they did so, a hardware module (microcontroller - MC) initiated one of the two light-emitting diodes (LED) that were placed within 30-cm-high cones (A & B). The athlete had to assess which cone was lit, shuffle to that particular cone, touch the top of the cone with their hand, shuffle back (from cone to point "X"), and run backward (from point "X" to start line) as quickly as possible. They then had to cross or step on the start line with their preferred leg, and run again over the next course. Every time athletes crossed the IR, the MC initiated one of the LED lights. A single test trial consisted in three courses and was completed when the participant crossed the IR beam after returning from the third course. All athletes were tested using three identical scenarios (i.e., identical sequences of LED lighting), though they had no knowledge of it in advance. The scenarios were A-A-B, B-A-A, and B-B-B. The CODS test was performed on the same testing field as the reactive-agility test (Figure 1). The testing scenario followed an A-B-A pattern, which the participants knew in advance. The timing began the moment each athlete crossed the IR. Athletes ran as quickly as possible to cone A (B) using the same movement template as throughout the reactive-agility test (forward running + lateral shuffling + lateral shuffling back + backward running to the start line).

For the reliability analysis, 21 participants (10 males and 11 females) were tested on CODS and reactive-agility test two days in a row using three trials (2 x 3 trials) presented in a random order (i.e. some participants performed CODS and then reactive-agility, while other did reactive-agility first, and then CODS) with a 5-7 min pause between trials. On the first testing day, the athletes familiarized themselves with the testing procedures by performing two-to-three practice trials prior to collecting data on both tests (i.e. CODS and reactive-agility), to establish their most convenient maneuvers.

The broad jump, 5-m sprint, and handball-specific test of non-reactive agility were done over three trials and the best score was retained as the final result of each participant.

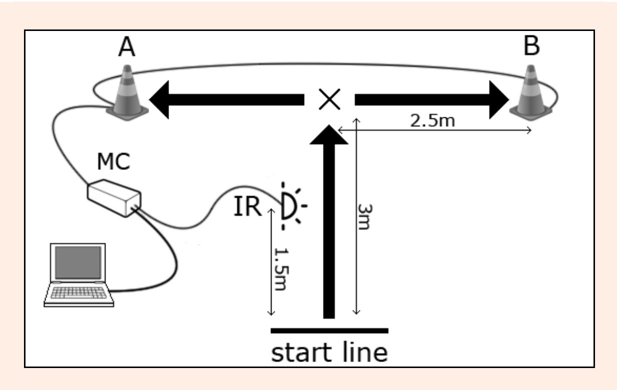

Figure 1. Testing of the handball-specific CODS and handball-specific reactive-agility (MC – microcontroller, IR – infrared sensor)

Statistical analysis

The Kolmogorov-Smirnov test defined all variables as normally distributed. Descriptive statistical parameters (mean and standard deviation) were calculated for all outcome measures.

The reliability analyses included calculation of the Intra-class-coefficients (ICC) and coefficients of variation (CV). Repeated measures ANOVA and Tukey post-hoc.

Table 1. **Reliability analyses. Data are presented as means (± standard deviations).**

	Males				Females			
	1st day	2nd day	CV	ICC	1st day	2nd day	CV	ICC
CODS (s)	6.94 (.47)	6.89 (.55)	.048	.91	7.46 (.37)	7.41 (.29)	.036	.93
Reactive-agility (s)	8.17 (.60)	8.19 (.71)	.030	.85	8.83 (.91)	8.92 (.98)	.024	.90

CODS – handball specific change of direction speed; Reactive-agility – handball specific test of reactive agility; CV – coefficient of variation; ICC – intra-class coefficient.

tests were used to detect any systematic bias between the individual trials (items) for each test

Differences between offensive- and defensive-players were assessed using Student't-test for independent samples. Additionally, differences were analyzed using a magnitude-based Cohen's effect size (ES) statistic with modified qualitative descriptors. Effect sizes were interpreted using these criteria: <0.2 = trivial, 0.2–0.6 = small, >0.6–1.2 = moderate, >1.2–2.0 = large, and >2.0 very large differences (Hopkins, 2014).

All the tests were considered significant at a 95% confidence level ($p < 0.05$). Statsoft's Statistic ver. 12.0 (Tulsa, OK, USA) was used for all analyses.

Results

The reliability parameters suggested a high consistency for reactive-agility-test and CODS-test (ICC of 0.85 and 0.91, and CV of 3% and 4.8% for reactive-agility and CODS, respectively in males; and ICC of 0.90 and 0.93, and CV of 2.4% and 3.6% for reactive-agility and CODS, respectively in females). The ANOVA showed no significant between-trial differences for both tests. Both males and females performed 15-20% better in the CODS than in the reactive-agility-test (Table 1).

Correlations between reactive-agility and CODS were significant ($r = 0.40$ and 0.42 for males and females, respectively; $p < 0.05$), demonstrating that reactive- and non-reactive-agility-test shared less than 20% of the common variance.

Among males, defensive players were significantly taller (moderate difference), and heavier (moderate difference). Male offensive players outperformed defensive players in CODS (moderate difference), while defensive players achieved significantly better results in P&RC (moderate difference). In males, offensive and defensive players did not differ significantly in 5-m sprint (small difference), broad-jump (trivial difference), and reactive-agility performance (trivial difference) (Table 2).

Female offensive players achieved significantly better in broad-jump than defensive players (moderate differences). Females involved in defensive duties were taller (small difference), and heavier (small difference), and had better P&RC (moderate differences). There was no significant difference between these two groups for CODS (small differences) reactive-agility (small differences), and 5-m sprint performance (small differences) (Table 3).

Discussion

There are several most important findings of this study. First, reliability of the newly developed test was satisfactory for both male and female athletes. Second, reactive-agility and CODS share less than 20% of the common variance. Third, the calculated index of perceptual and

Table 2. **Differences in CODS, reactive-agility and perceptual-and-reactive-index (P&RC) between offensive and defensive players among males. Data are presented as means (± standard deviations).**

	Offensive players	Defensive players	t-test		Effect size	
			T-value (p)	ES	-95%CI	+95%CI
Body height (m)	1.87 (5.48)	1.92 (5.44)	-2.28 (.02)	-.91	-1.48	-.31
Body mass (kg)	91.1 (9.3)	96.5 (7.7)	-2.13 (.02)	-.69	-1.25	-.10
Sprinting-5-meters (s)	1.04 (.06)	1.07 (.07	-1.40 (.08)	-.47	-1.03	.10
Broad jump (cm)	288.2 (13.0)	288.9 (27.6)	-.12 (.45)	.01	-.55	.57
CODS (s)	6.41 (.44)	6.82 (.37)	-1.75 (.04)	-.97	-1.64	-.26
Reactive agility (s)	8.33 (.69)	8.18 (.62)	.69 (.25)	.07	-.59	.74
P&RC (ratio)	.77 (.06)	.83 (.06)	-1.91 (.03)	-1.00	-1.68	-.29

CODS – handball specific change of direction speed; Reactive-agility – handball specific test of reactive agility; P&RC – index of perceptual and reactive capacity (ratio between achievement on CODS and Reactive-agility); CI – confidence interval

Table 3. **Differences in CODS, reactive-agility and perceptual-and-reactive-index (P&RC) between offensive and defensive players among females. Data are presented as means (± standard deviations).**

	Offensive players	Defensive players	t-test		Effect size	
			T-value (p)	ES	-95%CI	+95%CI
Body height (m)	1.76 (.06)	1.79 (.07)	1.89 (.04)	-.53	-.53	-1.28
Body mass (kg)	73.4 (9.3)	78.2 (7.1)	1.85 (.04)	-.59	-.59	-1.35
Sprinting-5-meters (s)	1.09 (.05)	1.12 (.08)	-.05 (.48)	-.49	-.49	-1.24
Broad jump (cm)	245.2 (19.5)	233.8 (15.6)	1.78 (.04)	.62	.62	.17
CODS (s)	7.36 (.42)	7.51 (.26)	-1.19 (.24)	-.40	-.40	-1.15
Reactive agility (s)	8.57 (.68)	8.96 (1.00)	-1.24 (.23)	-.49	-.49	-1.24
P&RC (ratio)	.81 (.06)	.86 (.07)	-1.99 (.03)	-.79	-.79	-1.55

CODS – handball specific change of direction speed; Reactive-agility – handball specific test of reactive agility; P&RC – index of perceptual and reactive capacity (ratio between achievement on CODS and Reactive-agility); CI – confidence interval reactive capacities is found as an applicable measure of true-game agility performance in handball.

Reliability of the newly constructed CODS- and reactive agility-test

Previous studies noted the necessity of developing sport-specific tests to assess reactive-agility in sports where this capacity is crucial (Gabbett and Benton, 2009; Sekulic et al., 2014). Overall, our results showed that the reliability of both newly developed tests (i.e. handball specific CODS- and reactive-agility-test) is high and similar to those previously reported for such performances (Oliver and Meyers, 2009; Sekulic et al., 2013; Sheppard et al., 2006). We must highlight that handball CODS test had a somewhat stronger reliability in both genders than the reactive-agility-test. However, this was expected because of the relative complexity of the reactive-agility test. More specifically, reactive-performance includes perceptual and reactive components, which are naturally sources of mistake, potential sources of measurement error, and consequently factors which could directly alter reliability (Sekulic et al., 2014).

Differences between CODS and reactive-agility were comparable in both genders (i.e. 15-20% better performance in CODS). It is important to note that previous studies reported almost identical differences when investigating other types of stop-and-go reactive agility in college-level athletes from different sports (Sekulic et al., 2014). Therefore, it seems that regardless of gender, duration of the test, and movement-template, the 15-20% difference should be considered as the average difference between reactive- and non-reactive- stop-and-go agility performances.

Handball-specific tests of CODS and reactive-agility shared less than 20% of common variance. This finding indicates that those two performances cannot be considered as a unique quality. Previous studies are not consistent with regard to the degree of association between reactive-agility and CODS. In short, authors who investigated rugby-specific reactive-agility over the Y-shape course reported practically negligible correlation between reactive-agility and CODS (Serpell et al., 2010). Meanwhile, in a recent investigation that introduced a general stop-and-go reactive-agility testing procedure, the correlation between CODS and reactive-agility was somewhat higher (0.62 and 0.68 for males and females, respectively, Sekulic et al., 2014).

The above-mentioned differences in correlation coefficients are most probably related to differences in tested participants, testing scenarios and durations of the tests between studies. Briefly, the rugby specific test was short in duration (less than 2 s) and consisted of only one change of direction, (Gabbett and Benton, 2009). In contrast, the handball-specific stop-and-go test presented in our study, as well as the previously reported general stop-and-go reactive-tests lasted considerably longer, consisted of several changes of direction and challenged participants to react repeatedly. This design may have increased the variance and numerical value of the correlation between CODS and reactive-agility-performance. Meanwhile, in the present study and the one performed on rugby athletes (Gabbett and Benton, 2009), participants were homogenous with regard to agility technique. This generally tends to truncate the variance of the tests, and consequently decrease the numerical value of the correlation coefficient (Huck, 2012). Collectively, these factors support the conclusion that reactive-agility and CODS are independent capacities.

Validity and applicability of the tests and derived P&RC index

The only truly valid test is a test which successfully differentiate between several groups of interest (Uljevic et al., 2014). For this purpose we have showed the validity of the reactive-agility-test by testing two groups of athletes. We hypothesized that those athletes who are regularly involved in defensive-duties will outperform those athletes who are not so frequently involved in such tasks during the handball game. Contrary to our initial considerations, the reactive-agility-performance of defensive-athletes was not superior. However, a more in depth analysis revealed some important facts. First, defensive athletes are significantly heavier (both males and females), and second, offensive athletes outperformed defensive athletes in several physical capacities (see Tables 2 and 3).

Significant differences in physical capacities between offensive and defensive athletes cannot be overlooked. Namely, offensive athletes achieved significantly better results in CODS (among males), and broad-jump (for females). Second, body mass is also an important factor influencing stop-and-go reactive-agility (Sekulic et al., 2014). Because of the tackle character of the defensive duties, defensive handball players have larger body mass (Michalsik et al., 2015). These suggest that despite the lack of significant difference between groups in reactive-agility, our results are clearly encouraging with regard to the true-game validity and the applicability of the tests we have designed and evaluated herein.

Previous studies indicated the potential importance of calculating the index of perceptual-reactive-capacity which is the ratio between CODS and reactive-agility done over the same course (P&RC index) (Sekulic et al., 2014). Namely, in defining ecologically valid tests of conditioning qualities in sports, one of the main issues relate to the applicability of specific physical capacities in real-sport environments (Sajber et al., 2013). In our study we have evaluated the percentage of the available optimal physical capacity (i.e. CODS) the athlete is able to evidence in real-sport-performance (i.e. reactive agility). Supportively, in both genders, athletes who are involved in defensive duties had better P&RC index, meaning that they had relatively smaller difference between CODS- and reactive-agility-performance. Therefore, and as hypothesized in previous studies, defensive athletes were more able to utilize a higher percentage of their current maximum physical capacity (i.e. CODS) in real-sport environment (i. e. reactive-agility) than offensive athletes (Sekulic et al., 2014).

Study limitations

The main limitation of this investigation comes from the fact that we studied adult athletes (i.e. adults) which limits the ability to generalize findings towards other populations (i.e. younger athletes). Knowing that the proposed tests are possibly applicable in talent identification in handball, future studies should explore the reliability and ecological validity of these tests in younger handball athletes. Also, the reactive-agility test validated in this study does not take into account any "cueing" factor that would allow the early identification of the opponent's movement pattern, which is an important issue in real-sport agility. Therefore, it should be explored more in depth in future studies.

Conclusion

The stop-and-go reactive agility and corresponding CODS should be considered as independent qualities, even when tested over the same course and similar movement patterns. The P&RC index derived from the CODS and reactive capacity performance appeared as valid indicator of defensive-specific reactive-agility performance in handball. However, although athletes involved in defensive duties do not necessarily have better reactive-agility, their reactive-agility-performance is closer to their non-reactive-agility-score (i.e. CODS).

Future studies should investigate other sport-specific CODS- and reactive-agility-testing protocols to replicate movement patterns which occur in real-game environment. This would be particularly important for goalkeepers because of the high importance of their reactive-capacities. Also, in-depth analyses of the factors associated with reactive-agility are needed.

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Key points

- Reactive agility and change-of-direction-speed should be observed as independent qualities, even when tested over the same course and similar movement template
- The reactive-agility-performance of the handball athletes involved in defensive duties is closer to their non-reactive-agility-score than in their peers who are not involved in defensive duties
- The handball specific "true-game" reactive-agility-performance should be evaluated as the ratio between reactive-agility and corresponding CODS performance.

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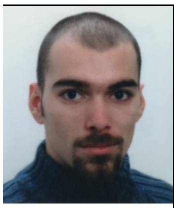

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