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CHANGE OF DIRECTION SPEED AND REACTIVE AGILITY PERFORMANCE – THE RELIABILITY OF A NEWLY CONSTRUCTED MEASURING PROTOCOLS: A BRIEF REPORT

HITROST SPREMEMBE SMERI IN IZVEDBA NEPROGRAMIRANE AGILNOSTI – ZANESLJIVOST NA NOVO ZASNOVANIH MERITVENIH POSTOPKOV: KRATKO POROČILO

ABSTRACT

Although the importance of reactive agility in sports is a known issue, there is only a limited number of reliable testing protocols for this capacity. The aim of this preliminary report was to evidence the reliability of a developed reactive agility testing procedure, and to present the construction of original testing equipment designed specifically for this purpose. The testing equipment is based on the ATMEL microcontroller AT89C51RE2 with a photoelectric infrared sensor as an external time triggering input, and LED illuminations as controlled outputs. A total of 63 well trained participants (39 males; age 21.1 ± 2.4 years) participated in the investigation. The procedures consist of three unpredictable (for reactive-agility) or three predictable (for non-reactive-agility) changes in running direction. Analyses were done separately for males and females. The results suggest that both tests are highly reliable (ICC ranged from 0.88-0.88; Cronbach Alpha: 0.78-0.85; Coefficient of Variation: 5-6%). ANOVA showed stabilization of the results until the third testing trial. The reactive and non-reactive agility performance carried out on the same court shared 36% and 42% of the common variance (for males and females, respectively). The simultaneous performance of both tests can be beneficial because the calculated ratio of scores will allow the indirect determination of the reaction qualities of tested subjects.

Key words: testing design, performance, stop-and-go agility, motor quality, conditioning capacities

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IZVLEČEK

Čeprav je pomen neprogramirane agilnosti že znan v športu, obstaja le nekaj postopkov testiranja te sposobnosti. V tem poročilu želimo potrditi zanesljivost zasnovanega postopka testiranja neprogramirane agilnosti in obenem predstaviti originalno opremo za testiranje narejeno posebej za ta namen. Oprema je zasnovana na mikrokontrolerju ATMEL AT89C51RE2 s fotoelektronskim infrardečim senzorjem kot zunanjim sprožilcem časa in kontrolno LED osvetlitvijo. V raziskavi je sodelovalo 63 telesno dobro pripravljenih merjencev (39 moških; starost: 21,1 ± 2,4 leta). Postopek je sestavljen iz treh predvidljivih (za programirano agilnost) in treh nepredvidljivih (za neprogramirano agilnost) sprememb smeri teka. Analize so bile izvedene ločeno za moške in ženske. Rezultati kažejo na visoko zanesljivost obeh testiranj (ICC med 0,88 in 0,88, koeficient Cronbach Alpha: 0,78 – 0.85, koeficient variacije: 5 – 6 %). ANOVA je pokazala stabilnost rezultatov vse do tretjega preizkusa testiranja. Izvedbi programirane in neprogramirane agilnosti na istem terenu sta si delili 36 % in 42 % skupne variance (za moške in ženske). Simultana izvedba obeh testov je koristna, saj bo izračunano razmerje rezultatov omogočilo neposredno določitev odzivnih lastnosti udeležencev testiranja.

Ključne besede: oblika testiranja, izvedba, agilnost, motorične lastnosti, telesna priprava.

INTRODUCTION

Agility is defined as the ability to efficiently change the direction (and/or speed) of movement in response to stimuli. This is an important motor quality in sports where changes in direction are common (Koklu, Alemdaroglu, Kocak, Erol, & Findikoglu, 2011; Milanovic, Sporis, Trajkovic, James, & Samija, 2013; Mirkov, Kukolj, Ugarkovic, Koprivica, & Jaric, 2010). However, in real-life sport situations changes in direction are almost exclusively made in response to unpredictable visual stimuli (Serpell, Ford, & Young, 2010; Sheppard, Young, Doyle, Sheppard, & Newton, 2006). Consequently, the term "reactive agility" is frequently used to describe a motor quality of agility that appears in sports (i.e. an effective change in direction in response to unpredictable visual stimuli) (Cochrane, 2013; Lockie, Jeffriess, McGann, Callaghan, & Schultz, 2013).

Studies have investigated reactive agility (Cochrane, 2013; Lockie et al., 2013; Oliver & Meyers, 2009; Serpell et al., 2010; Sheppard et al., 2006), but in most of the previous studies the test of reactive agility involved sprinting on a "Y-shaped" course where the subjects had to change their running direction only once during non-stop running. Yet, other sports evidently demand more specialized reactive agility tests (Serpell et al., 2010). This is particularly important in sports where repeated multidirectional "stop-and-go" reactive agility performance is common (i.e. football, basketball, handball) (Sekulic, Krolo, Spasic, Uljevic, & Peric; 2014; Spasic, Krolo, Zenic, Delextrat, & Sekulic, 2015).

The aim of this study was to construct and evaluate a measurement protocol which will be applicable in evidencing general multidirectional, stop-and-go reactive agility performance, using a convenient, reliable and multifunctional technological design. The first objective of this report was to present the idea, construction, and general technological design of the developed measurement tool. Next, we evaluated the within-subject and between-subject reliability of the testing protocol. Finally, since the tool allowed us to measure reactive- and non-reactive-component of agility, we established the relationship between these two qualities.

METHODS

Subjects

The subjects were physical education students (21.9±1.9 years in age). The total sample comprised 39 males (182.95±5.19 cm; 80.66±7.69 kg) and 24 females (171.45±6.81 cm; 61.95±6.70 kg). All of them were well trained, in good health, and had no recent history of musculoskeletal disorders.

All of the measurement procedures and potential risks were verbally explained to each participant and their informed consent was obtained. The Institutional Ethical Board reviewed the experimental procedures and gave its written consent.

Equipment

The first task of the study was to construct IT equipment that could be used to: (I) detect the movement; (II) trigger the random light signal; and (III) detect and record multiple time sequences. For this purpose, we constructed some digital equipment – a hardware device system. The system is based on the ATMEL microcontroller AT89C51RE2 that makes up the core of the system. System was previously tested and established tobe applicable in testing of the handball players and college-level athletes (Sekulic et al., 2014; Spasic et al., 2015). A photoelectric infrared sensor (IR; E18-D80NK) was used as an external time triggering input, with LED illuminations as controlled outputs. The IR that was used was proven to be as reliable as high-speed sensors; with a response time of less than 2 ms (>500Hz) and a digital output signal. The sensor's detection distance ranged from 3 cm to 80 cm, and was capable of detecting transparent or opaque objects. Because it has a digital output (high-low state) with a NPN transistor open collector, the sensor is connected through a microcontroller IO port. For the purposes of our study, this device was connected to a MAC platform that worked on a Mac OS, although a PC platform or other operating system (e.g., Windows, Linux, etc.) would also be suitable.

Variables and measurement

The reactive agility test was performed on the testing field shown in Figure 1. The subjects began running from the start line when ready. Timing began the moment each subject crossed the infrared signal (IR). When a subject broke the IR signal, a hardware module (microcontroller – MC) ignited one of the four LED lights placed inside 40-cm-high cones labeled A–D. A subject had to assess which cone was lit, run to that particular cone, touch the top of it with their preferred hand, and return to the start line as quickly as possible. They then had to cross or step on the start line with their preferred leg, turn, and continue running over the next course. Each time a subject crossed the IR, the MC turned on one of the LED lights. The single-test trial consisted of three courses, and was completed when a subject crossed the IR signal after returning from the third course. Three trials were performed. For the purpose of this study, all subjects were tested using three equal scenarios (i.e., three testing trials), although they had no advance knowledge of them. The first scenario was 1-3-4, the second was 2-2-4, and the third was 4-1-3. The best result was retained as the final score. Although the testing equipment was designed to allow a random selection of testing scenarios, the same three scenarios were used to assure equal testing conditions for all subjects.

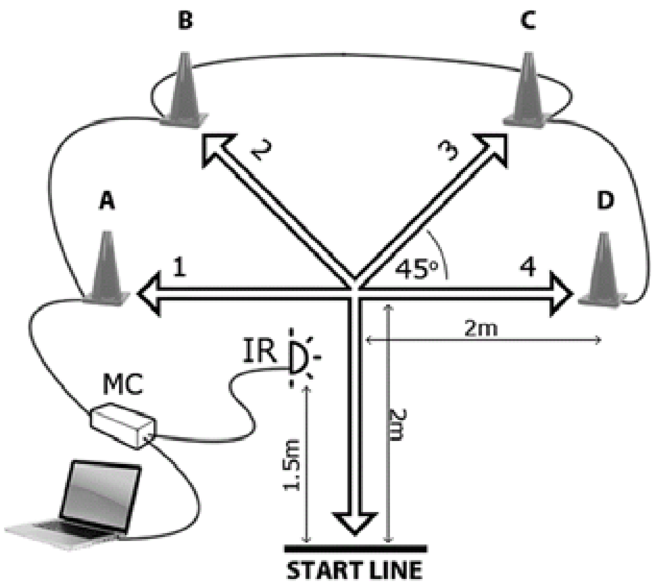

Figure 1: Testing design and equipment

The non-reactive agility test was performed on the same testing field (Figure 1). Throughout this test the testing scenarios were simple (1-2-3; 4-3-2; and 3-2-1), and the subjects knew them in advance. As for the reactive agility, the timing began the moment each subject crossed the IR. For the first testing trial, the subjects ran as quickly as possible to Cone A (Course 1), touched the top of the cone with their preferred hand and ran back to the start line. They then had to cross or step on the start line with their preferred leg, turn, and run over courses 2 and 3. The test was completed when a subject crossed the IR signal at the end of course 3. The same procedure was applied for the second (4-3-2) and third (3-2-1) scenarios.

Throughout the practice trials, prior to the reactive agility and non-reactive agility tests the subjects were familiarized with the testing procedures and established their most convenient maneuvers. More precisely, the participants were instructed to use their preferred movement procedure and type of running (i.e., forward, backward, lateral displacement, grapevine steps, etc.) and strive for their best score. One-half of the subjects conducted the reactive agility test first, followed by the non-reactive agility test, while the other half performed the non-reactive agility, then the reactive agility tests. Standardized 3-minute pauses between the trials and tests were introduced for all subjects.

Statistical Analyses

The within-subject and between-subject reliability of the applied measurements were checked via their coefficients of variation (CV), Cronbach Alpha values (CA), and Intra-class coefficients (ICC). An analysis of variance (ANOVA) for repeated measures and Tukey's post-hoc test were used to detect any systematic bias between the trials (items) for each test.

To determine the relationships between reactive agility and non-reactive agility, Pearson's correlations were calculated.

All analyses were performed separately for males and females. A level of 95% statistical significance was applied, and SPSS software (version 17; Chicago, Illinois) was used for all analyses.

RESULTS

Table 1: Reliability parameters for the stop-and-go reactive agility test, and stop-and-go non-reactive-agility for males

	Mean	SD	CA	CV	ICC
Reactive-agility1	7.352	0.568			
Reactive agility2	7.415	0.746			
Reactive agility3	7.377	0.619			
Reactive agility (s)	6.491	0.448	0.854	0.051	0.831
Non-reactive-agility1	6.666	0.545			
Non-reactive-agility2	6.302	0.425			
Non-reactive-agility3	6.253	0.410			
Non-reactive-agility (s)	5.700	0.489	0.783	0.049	0.855

Legend: SD – standard deviation; CA – Cronbach Alpha coefficient; CV – coefficient of variation; ICC – intra-class-coefficient ; subscripted numbers present trials

Table 2: Reliability parameters for the stop-and-go reactive agility test, and stop-and-go non-reactive-agility for females

	Mean	SD	CA	CV	ICC
Reactive-agility1	7.033	0.677			
Reactive agility2	6.850	0.660			
Reactive agility3	6.625	0.431			
Reactive agility (s)	6.989	0.580	0.822	0.053	0.871
Non-reactive-agility1	6.029	0.490			
Non-reactive-agility2	6.007	0.700			
Non-reactive-agility3	5.913	0.532			
Non-reactive-agility (s)	6.077	0.364	0.851	0.052	0.883

Legend: SD – standard deviation; CA – Cronbach Alpha coefficient; CV – coefficient of variation; ICC – intra-class-coefficient ; subscripted numbers present trials

Females and males performed better on non-reactive- than reactive-agility-test (14% and 13% for females and males, respectively). The between- and within-subject reliability of the reactive- and non-reactive agility tests is strong for both genders (Table 1 and 2).

Among the females, ANOVA found significant differences between the testing trials for reactive and non-reactive agility. However, significant post-hoc differences were only found between the 1st and 3rd testing trial (for both tests). There was no significant post-hoc difference between the 2nd and 3rd trials for any of the observed tests. Among the males, ANOVA for repeated measures reached statistical significance for reactive agility but, once again, post-hoc analysis showed the stabilization of the results until the third trial.

The correlations between the tests were significant ($p<0.05$) but moderate (0.60 and 0.65 for males and females, respectively), demonstrating that reactive and non-reactive agility share about 40% of the common variance (i.e. 36% and 42% for males and females, respectively).

DISCUSSION

Before discussing the main findings of the study, we must emphasize certain limits of this investigation. First, the study was performed on physical education students from different sports and therefore any generalization is limited.. Second, we focused solely on the reliability of the measurement and future studies are therefore needed to determine the validity of the applied instruments. However, this is one of the first investigations to evaluate reactive agility among trained athletes of both genders. Therefore, we believe that the findings of the study, although not the final word on the problem, should contribute to the body of knowledge in the field.

Non-reactive agility is known as a multifaceted quality with different possible movement scenarios (forward running, backward running, lateral shuffling, stop-and-go, zig-zag, etc.). Therefore, the authors were naturally interested in the reliability of different testing procedures in both sexes. In comparison to previous reports, we can emphasize the high reliability of the non-reactive agility testing studied here (Sekulic, Spasic, & Esco, 2014; Spasic, Uljevic, Coh, Dzelalija, & Sekulic, 2013; Sporis, Jukic, Milanovic, & Vucetic, 2010). This is particularly valuable because the non-reactive agility-test we studied is relatively complex, and consists of three courses and five changes in direction. In the meantime, most common non-reactive agility tests, such as the 20-yard-test, forward-backward running; 180 degrees turn-test, or zig-zag test, comprise three to a maximum of four changes in direction (D. Sekulic, Spasic, Mirkov, Cavar, & Sattler, 2013; Sporis et al., 2010). Since each single change in direction naturally increases the error of the measurement (due to non-controllable factors such as incorrect stepping, a wrong turn, etc.), the high level of reliability achieved by the non-reactive test we have developed is even more important.

Apart from recently presented studies that identified the problem of stop-and-go agility (D. Sekulic et al., 2014; Spasic et al., 2015) and identified different templates in testing it, most of the previous studiesinvestigated one particular test consisting of an agility maneuver performed on a Y-shaped course. In this test, the subjects had to perform a single change in direction (i.e. the subjects started at the bottom of the Y-shape and changed direction in the middle of the course). In general, the reliability of the explained procedure was strong, with ICC ranging from 0.82 to 0.90 (Serpell et al., 2010; Sheppard et al., 2006). However, there are several crucial differences between the said Y-shaped-based reactive agility test and the reactive agility test we presented here. First, the Y-shaped test only includes a single change in direction, and the average achievement was less than 2 seconds. At the same time, in the reactive agility test presented here the subjects changed their direction more often (i.e. three times in response to unpredictable stimuli), and the average achievement was more than 6 seconds. Next, with the Y-shaped course there is a 50% possibility that a subject will "guess" the directional change (i.e. since there are only two possible directions), whereas in our test such a probability is 25% (four potential directional changes; see Figure 1). Third, contrary to our stop-and-go agility performance, the previously reported Y-shaped test consists of non-stop running (i.e. there is no "zero-velocity" moment in the test). Knowing that recent studies highlighted the differential background to stop-and-go and non-stop agility, this points to a differential application of the two measuring protocols (Sekulic et al., 2014; Spasic et al., 2013).

We must acknowledge that our respected colleagues originally developed the Y-shaped-course test with specific movement templates in the sport of rugby in mind, and that such a testing approach is clearly sport-specific and therefore logical (Sheppard et al., 2006). In the meantime, our intention was to develop a reactive agility test that would allow the testing of activity-specific reactive agility for those sports where a multidirectional stop-and-go reactive change in direction appears (i.e. football, basketball, handball). Since the reliability parameters we found are similar to those previously reported for Y-shaped-based agility-test, we can highlight the low measurement error and proper consistency of the test we have developed. To the best of our knowledge, this is the one of the first studies to have investigated a reactive agility test among females. In a recent one, authors presented specific handball reactive-agility test and reported reliability similar to this one presented herein ((Spasic et al., 2015). Therefore, the reliability we found for female particpants studied herein (i.e. physical education students) is comparable to levels previously reported. Yet, since the reliability of the reactive agility testing does not vary between genders, whereas the between-subject reliability is even stronger for females, we may underline the low measurement error of the proposed testing procedure among female physical education students.

ANOVA indicated that the testing of both procedures should involve at least two trials. More precisely, the authors of the study witnessed one common mistake that characterized the first trials. Initially, most subjects tried to sprint at maximum speed from the start line to the infrared sensor.

As a result, they accelerated uncontrollably and their inertia did not allow them to efficiently make the necessary change in direction. By the second or third trial they had anticipated this problem, consequently leading to their superior and stable performances in the remaining trials. Therefore, we must emphasize the necessity of several testing trials in evaluation of such kind of performance. Namely, while agility is complex motor ability that relates to different backgrounds (speed, balance, power), the complex-agility-performance, as the one studied herein, should be tested over the multiple testing trials. In doing so, proper familiarization would be highly beneficial (Amarante do Nascimento et al., 2013).

Since both tests were performed on a similar course, the significant correlation found between the reactive and non-reactive performances was expected. Namely, regardless of the fact that for the non-reactive-test examinees knew the directional changes in advance, which was not the case with the reactive agility test, both tests clearly depend on certain equal capacities such as power, speed, and balance (Sekulic et al., 2013). The unexplained part of the variance (i.e. 64% and 58% for males and females, respectively) is almost certainly related to the subjects' perceptual and reactive capacities, which are only challenged in the reactive agility test (Serpell et al., 2010). In previously cited studies that investigated Y-shaped-based reactive agility, authors found practically a null-correlation between reactive and non-reactive agility, but this is understandable given the differences in the testing procedures (i.e. non-stop vs. stop-and-go performance, one-directional vs. multidirectional change in direction, etc.) (Serpell et al., 2010). On the other hand, very recent study done on handball athletes reported 15% of the common variance between reactive-agility and change-of-direction-speed tested over the same course (Spasic et al., 2015). Consequently, it seems that regardless of the testing design and movement technique (i.e. handball athletes were tested by means of lateral displacement), the stop-and-go-agility and change-of-direction-speed share less than 20% of the common variance.

CONCLUSION

This study investigated physical education students with different agility-background. Therefore, the performances in both tests applied are probably highly influenced by their technique and characteristic movement efficacy, irrespective of other qualities known to be important for agility-performance. However, our idea was to evaluate the general testing protocol that will allow testing of variable samples of subjects, such as the one observed herein.

Since agility performance in sports directly depends on an effective response to unpredictable (visual) stimuli, understanding of this quality (i.e. perceptual and motor capacities) can be highly valuable for sport selection, sport orientation, and goal-oriented sport conditioning.

Finally, the results of this study permit us to conclude that reactive and non-reactive agility should be observed as two separate capacities in both males and females. It points to the necessity of independent evaluation of both qualities in sports where agility is important factor of success.

REFERENCES

Amarante do Nascimento, M., Januario, R. S., Gerage, A. M., Mayhew, J. L., Cheche Pina, F. L., & Cyrino, E. S. (2013). Familiarization and reliability of one repetition maximum strength testing in older women. *J Strength Cond Res, 27*(6), 1636-1642. doi: 10.1519/JSC.0b013e3182717318

Cochrane, D. J. (2013). The effect of acute vibration exercise on short-distance sprinting and reactive agility. *J Sports Sci Med, 12*(3), 497-501.

Koklu, Y., Alemdaroglu, U., Kocak, F. U., Erol, A. E., & Findikoglu, G. (2011). Comparison of chosen physical fitness characteristics of Turkish professional basketball players by division and playing position. *J Hum Kinet, 30,* 99-106. doi: 10.2478/v10078-011-0077-y

Lockie, R. G., Jeffriess, M. D., McGann, T. S., Callaghan, S. J., & Schultz, A. B. (2013). Planned and Reactive Agility Performance in Semi-Professional and Amateur Basketball Players. *Int J Sports Physiol Perform.*

Milanovic, Z., Sporis, G., Trajkovic, N., James, N., & Samija, K. (2013). Effects of a 12 Week SAQ Training Programme on Agility with and without the Ball among Young Soccer Players. *J Sports Sci Med, 12*(1), 97-103.

Mirkov, D. M., Kukolj, M., Ugarkovic, D., Koprivica, V. J., & Jaric, S. (2010). Development of Anthropometric and Physical Performance Profiles of Young Elite Male Soccer Players: A Longitudinal Study. *Journal of Strength and Conditioning Research, 24*(10), 2677-2682. doi: Doi 10.1519/Jsc.0b013e3181e27245

Oliver, J. L., & Meyers, R. W. (2009). Reliability and generality of measures of acceleration, planned agility, and reactive agility. *Int J Sports Physiol Perform, 4*(3), 345-354.

Sekulic, D., Krolo, A., Spasic, M., Uljevic, O., & Peric, M. (2014). The development of a new stop'n'go reactive-agility test. *J Strength Cond Res, 28*(11), 3306-3312. doi: 10.1519/JSC.0000000000000515

Sekulic, D., Spasic, M., & Esco, M. R. (2014). PREDICTING AGILITY PERFORMANCE WITH OTHER PERFORMANCE VARIABLES IN PUBESCENT BOYS: A MULTIPLE-REGRESSION APPROACH 1. *Perceptual & Motor Skills.*

Sekulic, D., Spasic, M., Mirkov, D., Cavar, M., & Sattler, T. (2013). Gender-specific influences of balance, speed, and power on agility performance. *J Strength Cond Res, 27*(3), 802-811. doi: 10.1519/JSC.0b013e31825c2cb0

Serpell, B. G., Ford, M., & Young, W. B. (2010). The development of a new test of agility for rugby league. *J Strength Cond Res, 24*(12), 3270-3277. doi: 10.1519/JSC.0b013e3181b60430

Sheppard, J. M., Young, W. B., Doyle, T. L., Sheppard, T. A., & Newton, R. U. (2006). An evaluation of a new test of reactive agility and its relationship to sprint speed and change of direction speed. *J Sci Med Sport, 9*(4), 342-349. doi: 10.1016/j.jsams.2006.05.019

Spasic, M., Krolo, A., Zenic, N., Delextrat, A., & Sekulic, D. (2015). Reactive Agility Performance in Handball; Development and Evaluation of a Sport-Specific Measurement Protocol. *J Sports Sci Med, 14*(3), 501-506.

Spasic, M., Uljevic, O., Coh, M., Dzelalija, M., & Sekulic, D. (2013). Predictors of agility performance among early pubescent girls. *International Journal of Performance Analysis in Sport, 13*(2), 480-499.

Sporis, G., Jukic, I., Milanovic, L., & Vucetic, V. (2010). Reliability and factorial validity of agility tests for soccer players. *J Strength Cond Res, 24*(3), 679-686. doi: 10.1519/JSC.0b013e3181c4d324