Association of Speed of Decision Making and Change of Direction Speed With The Agility Performance

Erika Zemková; Dušan Hamar

Abstract
The study investigates the relationship between agility time and both two-choice reaction time and movement time in athletes of various specializations. Groups of 18 karate-kumite competitors, 12 tae-kwon-do competitors, 10 ball hockey players, 21 soccer players, and 27 physically active men performed two-choice reaction test, visually-triggered step initiation test, pre-planned and reactive agility tests with different traveling distances. Results showed a significant correlation between agility time and two-choice reaction time ($r$ ranged from .94 to .92, $P < .01$), regardless of sports specialization of athletes or their previous experience with agility training. Agility time significantly correlated also with the movement time ($r$ ranged from .78 to .75, $P < .05$), however only when traveling a short distance between mats. The strength of this relationship decreased with increasing traveling distances. Simple regression analyses revealed that a 13% decrease in agility time was associated with shorter two-choice reaction time, whereas only 5% decrease in agility time was accompanied with shorter movement time. In addition, the coefficient of variation was higher for movement time than two-choice reaction time (9.7% and 5.2%, respectively). These findings indicate that both speed of decision making and change of direction speed contribute to the agility performance, although to a different extent. In the case of sprinting, it mainly depends on distance traveled. Greater variation in the movement time than two-choice reaction time also makes potentially meaningful differences among athletes (particularly among those of combat sports and sports games) and their differential contribution to the agility time. Therefore, sport-specific methods should be addressed in both agility testing and training.

Introduction
Agility is defined as a rapid, whole-body, change of direction or speed in response to a sport-specific stimulus.1 This suggests that agility contains both perceptual and decision making in addition to a change of direction movement component.1,2 However, contradictory findings exist on contribution of speed of decision making and change of direction speed to the agility performance. For instance, Young and Willey3 discovered that of the three components that make up the total time, decision time had the highest correlation ($r = .77, P = .00$) with the total time. This correlation with total time was greater than for response movement time ($r = .59$) or tester time ($r = .37$). This indicates that decision time was the most influential of the test components for explaining the variability in total time. The decision time component within the reactive test condition also revealed that the highly-skilled players made significantly faster decisions than the lesser-skilled players.4 The results of Gabbett and Benton5 also demonstrate that the decision and movement times on the reactive agility test were faster in higher-skilled players, without
compromising response accuracy. Similarly, Serpell et al. revealed a significant difference in mean time in the sport-specific reactive agility test (RAT) between the elite group and the subelite group of the rugby league. Performance differences on the RAT were attributed to differences in perceptual skills and/or reaction ability. The review of Paul et al. showed that decision-making and perceptual factors are often propositioned as discriminant factors; however, the underlying mechanisms are relatively unknown.

Contrary to this, a little is known about the contribution of linear and/or change of direction speed to the reactive agility. More research attention has received their relationship with pre-planned agility. Some research evidence indicates low and moderate relationships between straight sprinting and sprints with directional change.8-10

Accordingly, the common variance between the open skill test (reactive agility test) and the closed skill speed tests (straight sprinting test or change of direction speed test) is relatively low. For example, Draper and Lancaster found a significantly low to moderate correlation between straight sprinting ability and Illinois agility test that involved some straight sprinting and multiple direction changes around obstacles. Also Buttifant et al. reported poor correlations between the performance of change of direction speed (CODS) test and straight sprint test in soccer players who performed a 20 m straight sprint and a generic CODS test, involving four directional changes of approximately 20 m. Furthermore, Baker discovered that two groups of elite and developmental rugby league players were similar in their straight running speed, but the elite players performed better in tests that involved change of direction. Another study by Young et al. compared straight sprinting, sprinting while bouncing a football, sprinting with three planned directional changes at 908 angles, sprinting with three planned directional changes at 908 angles while bouncing a football, and sprinting with three directional changes at 1208 angles, in Australian Rules football players. The authors found very low correlations between sprint and agility tests, indicating that sprinting, sprinting while bouncing a ball and sprinting while changing direction were distinct and specific qualities. Also Tsitskarsis et al. reported a weak relationship between straight sprinting ability and the ability to perform complex tasks such as dribbling a basketball.

Similarly, Gabbett et al. revealed no significant relationships among measures of linear speed and change of direction speed, however movement times on the reactive agility test were significantly related to 10 m and 20 m sprint times and change of direction speed. Significant correlation was also found between speed in straight sprint test and change of direction speed test ($r = .738, P < .01$) with a common variance of 54%.16 In addition, there were significant correlations between the variables of reactive agility test and both straight sprint test ($r = .333, P < .05$) and change of direction speed test ($r = .321, P < .05$). Nevertheless, the common variance among these tests was only 11% and 10%, suggesting that these two tests are measuring distinct qualities. In contrast, Oliver and Meyers reported a high degree of common variance between acceleration times and both planned ($R^2 = .93$) and reactive ($R^2 = .83$) agility, as well as between the two agility protocols ($R^2 = .87$).

These equivocal findings raise a question whether enhanced agility performance is associated with advanced perceptual skills, while also highlighting the contribution of movement speed. With reference to these studies, we expected (1) significant correlations between agility time and both choice reaction time and movement time; and (2) that the strength of association between these components depends on sports specialization of athletes due to different distances traveled during the match. To test these assumptions, we investigated the relationship between agility time and both two-choice reaction time and movement time in groups of athletes with diverse demands on speed of decision making and change of direction speed in their performances.

### Methods

#### Participants

Altogether 88 athletes of combat sports and sports games in which agility skills play an essential role and a control group of physically active men volunteered to participate in the study (Table 1). All athletes had over 10 years’ experience in particular sports with at least 6 years’ experience in a competition. Those who met the inclusion criteria were allocated to the study. Approximately 79% of the athletes enrolled in the selected sports clubs participated. Age matched group of physically active men had no experience in agility training. All participants were asked to avoid any strenuous exercise for the duration of the study. They were informed of the procedures and main purpose of the study. The procedures presented were in accordance with the ethical standards on human experimentation as stated in the Helsinki Declaration.

#### Procedures

Prior to the study, participants attended a familiarization session during which the testing conditions were explained and trial sets carried out. They were encouraged to practice the measurement procedure

<table>
<thead>
<tr>
<th>Groups of athletes</th>
<th>n</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Body mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karate-kumite competitors</td>
<td>18</td>
<td>24.7 ± 3.2</td>
<td>178.5 ± 7.9</td>
<td>73.9 ± 9.2</td>
</tr>
<tr>
<td>Tae-kwon-do competitors</td>
<td>12</td>
<td>23.2 ± 2.7</td>
<td>179.2 ± 8.6</td>
<td>74.6 ± 10.0</td>
</tr>
<tr>
<td>Ball hockey players</td>
<td>10</td>
<td>25.5 ± 3.5</td>
<td>182.2 ± 9.2</td>
<td>78.6 ± 13.8</td>
</tr>
<tr>
<td>Soccer players</td>
<td>21</td>
<td>22.7 ± 2.4</td>
<td>178.6 ± 7.5</td>
<td>77.5 ± 11.9</td>
</tr>
<tr>
<td>Physically active men</td>
<td>27</td>
<td>22.2 ± 1.9</td>
<td>181.7 ± 8.6</td>
<td>79.9 ± 15.6</td>
</tr>
</tbody>
</table>

Table 1. Participant characteristics (mean ± SD).
beforehand in order to eliminate unfamiliarity with the exercise. Afterwards they performed the reaction test, step initiation test and agility tests. The reliability of test procedures was previously verified and testing protocols were standardized.18

**Two-choice Reaction Test.** Participants were required to respond to two visual stimuli in the form of a circle, square, triangle or cross positioned on mats on the floor. The mats had to be touched in accordance with the stimulus on the screen. Participants were instructed to keep their legs as close as possible to the mats in order to eliminate the influence of their leg movements on the outcome. They performed three trials of 40 responses. Data from the best trial of 2-choice reaction time were selected for analysis.

Reaction time was measured using a diagnostic system FiTRO Reaction Check (FiTRONiC, Slovakia) that consists of two contact switch mats connected by means of an interface to a computer. A special software measures the time the subject requires to accomplish leg contact with the mat corresponding to the stimulus on the screen. Software enables storage, analysis and extensive reporting of the data.

**Visually-triggered Step Initiation Test.** Participants performed 3 trials of 2-choice stepping reactions to visual stimuli. The test was initiated with the participant standing on two mats placed in front of the light signals. When the light switched on, the participant performed two steps (starting with dominant leg) moving to mats (with 30 cm sides) marked with tape on a floor with a 60 – 70 cm distance apart. Participants were instructed to perform the steps as quickly as possible. The time of foot off (onset of unloading) and foot contact time (from foot-off to foot-contact) of the first step were recorded by means of the FiTRO K-Reaction Check (FiTRONiC, Slovakia).

Concurrently with measuring reaction and movement times, the maximal step velocity was measured using the FiTRO Dyne Premium system (FiTRONiC, Slovakia). The device was anchored to the wall and tethered by a nylon rope to the ankle of the participant. The participant was instructed to perform, as quickly as possible, the steps while pulling the nylon tether of the device. The system consists of a sensor unit based on a precise encoder mechanically coupled with a reel. While pulling the tether (attached to the ankle of the participant) the reel rotates and measures velocity. Signals from a sensor unit are conveyed to the computer by means of a USB cable. Comprehensive software allows the collection, calculation and on-line display of the basic parameters involved in step execution. Data from the best of 3 trials were utilised for analysis.

**Reactive and Pre-planned Agility Tests.** Participants were required to touch, as quickly as possible, with either the left or the right foot, one of four mats located in the four corners outside of a pre-defined square. Mats had to be touched in accordance with the location of a stimulus in one of the corners of the screen. The test consisted of pre-defined number of visual stimuli with random generation of their location on the screen and a time generation from 500 to 2500 ms while traveling varied distances (Table 2). The result was the sum of previously determined numbers of agility times taken from the better of two trials.

Participants were required to perform the agility test over two sessions spaced 2-3 days apart. The only difference in the second case was that they did not respond to visual stimuli while traveling different distances between mats. Otherwise, the testing procedure and time of day were identical for all subjects. The same experienced researchers conducted the measurement procedures during both testing sessions.

Agility time was measured by means of the computer based system FiTRO Agility Check (FiTRONiC, Slovakia). The system consists of contact switch mats connected by means of an interface to the computer. A special software measures the time required by the participant to establish foot contact with the mats, corresponding with the position of stimulus located in one of the four corners of the screen. Software enables storage of the data, their analyses and extensive reporting.

**Statistical Analyses**

Data analysis was performed using the statistical program SPSS for Windows version 18.0 (SPSS, Inc., Chicago, IL, USA). Data are presented as mean ± standard deviation (SD).

The calculation of the sample size was conducted with α = 0.05 (5% change of type I error) and 1 - β = 0.80 (power 80%) and using the results from our previous studies that identified significant differences in agility time among athletes of various sports. This provided a sample size of 16 for this study. Though the sample size in two groups was below this limit, because the inclusion criteria required participants to be active in a particular sport, groups of athletes of combat sports and sports games were sufficient for finding statistically significant differences.

One way analysis of variance (ANOVA) was used to estimate significant between-group differences in two-choice reaction time, movement time and/or maximal step velocity, and agility time. The level for statistical significance was set at $P < .05$. Where the results of ANOVA indicated significant $F$-ratios between groups, the Scheffé test was applied post hoc to determine in which groups the differences occurred. Sex data, determined to be normally distributed, were analyzed in previous

<table>
<thead>
<tr>
<th>Distance covered (m)</th>
<th>Number of stimuli (1)</th>
<th>Number of best responses used for the analysis (1)</th>
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<tbody>
<tr>
<td>0.8</td>
<td>40</td>
<td>32</td>
</tr>
<tr>
<td>1.6</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>3.2</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>
studies using the independent samples t test and showed no significant differences in agility time between men and women. Nevertheless, only male athletes were selected for the present study. This was because longer movement distances were used in this study in comparison with the original version of the agility test, which could lead to different physiological responses and consequently affect the outcome in female and male athletes.

Association between agility time and two-choice reaction time, movement time and/or maximal step velocity was assessed by calculating Pearson's product moment correlation coefficient. Total variance is reported by the coefficient of determination. The level of significance was set at α = 5%.

**Results**

Results identified that two-choice reaction time was significantly lower in athletes of combat sports than sports games (9.0%, P = .036). However, there were no significant differences between these groups of athletes in movement time (2.4%, P = .503) and/or maximal step velocity (2.7%, P = .464) in the visually-triggered step initiation test. Consequently, the agility time was significantly lower in athletes of combat sports than sports games (13.8%, P = .041). Their values in these two groups of athletes were significantly lower as compared to the control group of physically active men (21.0%, P = .007, 11.1%, P = .016, 13.8%, P = .021, and 16.7%, P = .009, respectively).

On the other hand, movement time was significantly better in athletes of sports games than combat sports, however only when traveling longer distances of 3.2 m (17.1%, P = .008) and 1.6 m (12.9%, P = .027). The values did not differ significantly between these groups at a distance of 0.8 m (6.2%, P = .110). Similarly, agility time was significantly better in athletes of sports games than combat sports when traveling distances of 3.2 m (21.6%, P = .006) and 1.6 m (14.2%, P = .019), whereas there were no significant differences between these groups at a distance of 0.8 m (6.9%, P = .076). These athletes showed significantly lower values of movement time and agility time as compared to the control group of physically active men at distances of 0.8 m (16.1%, P = .016 and 23.9%, P = .007, respectively), 1.6 m (19.9%, P = .009 and 32.0%, P = .002, respectively), and 3.2 m (22.0%, P = .007 and 34.6%, P = .001, respectively).

Additionally, there were significant correlations between agility time and two-choice reaction time (r = .934, P = .007) as well as agility time and movement time (r = .771, P = .033) or maximal step velocity (r = .832, P = .027) when the agility test with a short distance between mats was used. More specifically, agility time highly correlated with two-choice reaction time in athletes of both combat sports (r = .941, P = .001, 95% CI [.875 to .977]) and sports games (.933, P = .001, 95% CI [.840 to .980]) as well as in the control group of physically active men (.924, P = .003, 95% CI [.817 to .983]) and this represented a common variance of 93%, 90% and 88%, respectively. Likewise, there was a significant correlation between agility time and movement time in combat sports athletes, however only at a short distance of 0.8 m (Table 3). The R² values ranged from .65 to .29, explaining 65–29% of total variance. When considering participants involved in sports games, the strength of relationships between agility time and movement time also decreased with increasing traveling distances (Table 3). The R² values ranged from .57 to .34, explaining 57–34% of total variance. A similar tendency was observed for the relationships between agility time and movement time in a group of physically active men (Table 3). The R² values ranged from .54 to .19, explaining 54–19% of total variance.

Simple regression analyses revealed that a 13% decrease in agility time was associated with shorter two-choice reaction time, whereas only 5% decrease in agility time was accompanied with shorter movement time.

Furthermore, the coefficient of variation was higher for movement time than two-choice reaction time (9.7% and 5.2%, respectively). In particular, its values were greater in athletes of sports games as compared to those of combat sports, especially at longer distances traveled (1.6 m and 3.2 m).

**Discussion**

Our results showed significant correlations between agility time and two-choice reaction time as well as agility time and movement time and/or maximal step velocity in the agility test with a short distance between mats. Further analysis revealed that agility time highly correlated with two-choice reaction time in athletes of both combat sports and sports games as well as in the control group of physically active men (r ranged from .94 to .92). This represented a common variance in range from 93 to 88%. However, the strength of relationships between agility time and movement time decreased with increasing traveling distances between mats in athletes of combat sports (r ranged from .78 to .48) and sports games (r ranged.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Traveling distance (m)</th>
<th>r (95% confidence interval)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combat sports athletes</td>
<td>0.8</td>
<td>.778 [.576 to .896]</td>
<td>.016</td>
</tr>
<tr>
<td>Game sports players</td>
<td>0.8</td>
<td>.751 [.489 to .889]</td>
<td>.031</td>
</tr>
<tr>
<td>Physically active men</td>
<td>0.8</td>
<td>.766 [.548 to .911]</td>
<td>.024</td>
</tr>
</tbody>
</table>

Table 3. Correlations between agility time and movement time when traveling different distances in athletes of combat sports, sports games and a group of physically active men.
from .77 to .55). This represented a common variance in range of 65–29% and 57–34%, respectively. A significant correlation between agility time and movement time was also found in a group of physically active men, but only at a distance of 0.8 m ($r = .75$) and not at distances of 1.6 m ($r = .41$) and 3.2 m ($r = .38$), explaining 54–19% of total variance.

Although covering the same total distance, the protocols used in the present study involved more multiple direction changes over a short distance (40 × 0.8 m) compared to those designed for longer distances (20 × 1.6 m and 10 × 3.2 m). Results confirmed our assumption that the strength of associations between agility time and movement time decreases when the former is measured over longer distances. Relative speed of the first acceleration step appears to be an important component in determining change of direction ability over short distances.19 This is consistent with previous studies that reported acceleration as an important aspect in agility and change of direction movement.1,10,20,21 However, the ability to decelerate CoM rapidly is also a key component of change of direction ability.19 When undertaking a 180° change of direction test, deceleration movement times are extremely variable within and between individuals, particularly when compared with acceleration movement times.19 Accordingly, the change of direction tests evaluate an athlete’s ability to rapidly decelerate and reaccelerate in the new direction. When longer distances are covered, the total running time contains both change of direction ability and straight-line sprinting.

Based on the data available, it appears that the relationship between straight sprinting speed or change of direction speed and the reactive agility depends on distance covered in these tests. Indeed, there is evidence that performance in the change of direction test more strongly correlates with acceleration speed than with maximum running speed.13,22,23 Therefore, stronger correlation may be assumed between maximal step velocity and agility time over shorter than longer distances.19 This is consistent with previous studies that reported a higher proportion of straight sprinting in the agility test, deceleration movement times are extremely variable within and between individuals, particularly when compared with acceleration movement times.19 Accordingly, the change of direction tests evaluate an athlete’s ability to rapidly decelerate and reaccelerate in the new direction. When longer distances are covered, the total running time contains both change of direction ability and straight-line sprinting.

Significant correlations were also observed between agility time and movement time, however only when traveling a short distance between mats. This may be more likely ascribed to the contribution of speed of step initiation to the agility performance. This assumption may be corroborated by significant correlation between maximal step velocity and agility time. However, the strength of this relationship decreased with increasing traveling distances between mats. It is therefore likely that acceleration and deceleration phases determine the agility performance more over shorter than longer distances. A larger proportion of straight sprinting in the agility test resulted in weaker relationship between these two components. This is in agreement with previous studies.
reporting low and moderate relationships between straight sprinting and sprints with directional change. The common variance between these two measures is relatively low, which also suggests that change of direction sprinting without and with responses to visual stimuli are relatively independent qualities. Therefore, methods used for pre-planned and reactive agility testing and training should be specific to demands of particular sports.

Conclusions
Both speed of decision making and change of direction speed contribute to the agility performance, although to a different extent. Agility time strongly correlates with the choice reaction time, regardless of sports specialization of athletes or their previous experience with agility training. This indicates that perception and decision making are the most influential components of agility performance. There is also a significant correlation between agility time and movement time, however only when traveling a short distance between mats. The strength of this relationship decreases with increasing traveling distances. It is therefore likely that acceleration and deceleration phases determine the agility performance more over shorter than longer distances. Greater variation in the movement time than two-choice reaction time also makes potentially meaningful differences among athletes (particularly among those of combat sports and sports games) and their differential contribution to the agility time. Therefore, sport-specific methods should be addressed in both agility testing and training.

Acknowledgement
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References