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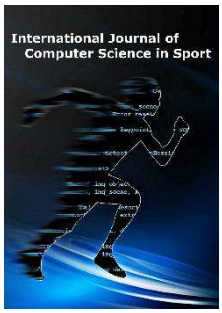

Sport-specific differences in key performance factors among handball, basketball and table tennis players

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Abstract

Change of direction speed, reaction time, sprint speed, and explosive strength are important factors that determine athletes‘ performance in the majority of sports. From the practical standpoint, it is of interest to investigate to what extent they differ among athletes of team and individual sports. We compared 7 handball, 11 basketball, and 15 male table tennis players in four reaction time tests, 505 Agility test, 5m and 20m sprints, squat, countermovement, and drop jumps. Basketball players performed better in reaction time to fast generating stimuli (12.6%, p=.001) and countermovement jump height (14.5%, p=.05) than handball players. In addition, they achieved a higher reactive strength index (25%, p=.01) than table tennis players. Handball players were faster in the 505 Agility test compared to table tennis players (4.6%, p=.04). Results revealed that performance of basketball players is mainly determined by explosive strength, handball players by change of direction speed, and table tennis by speed of response to visual stimuli. These differences may be ascribed to long-term adaptation to sport-specific stimuli. Novel assessment methods and devices should better determine key performance factors of athletes with regard to sport-specific tasks.

KEYWORDS: ATHLETIC PERFORMANCE, INDIVIDUAL SPORTS, TEAM SPORTS, TESTING, REACTION TIME.

Introduction

The physical capabilities of athletes are fundamental for performance in a variety of sports. Specifically, explosive strength, sprinting and change of direction speed (CODS), reaction speed, and decision-making ability, appear to be important factors of athletic performance in invasive and racquet sports (Bhabhor et al., 2013; Vikashpaul and Bhat, 2019; Picabea, Cámara, & Yanci, 2021). However, sport-specific differences in strength (Suchomel, Nimphius, & Stone, 2016), endurance, and speed (Billaut, Gore, & Aughey, 2012) exist among players of different specializations.

Physiological differences in motor performance are significant among high-level team sport players (Peña et al., 2018). For example, basketball players overperform handball players in lower-limb explosive strength and linear sprinting speed parameters (Bhadu and Singh, 2016). On the other hand, only a slight difference is detectable in the agility performance among youth players competing in the open-skill environment (Šimonek, Horička, & Hianik, 2017). Performing in rapidly changing and unpredictable game conditions demand players' visual attention, perception, and quick reaction to external stimuli (Voss et al., 2010). Therefore, additional important aspects of performance in invasive sports are reaction time and decision-making speed (Young, Dawson, & Henry, 2015).

Particularly, reaction time is a key variable of players' performance in table tennis (Castellar et al., 2019). Although reaction speed is also important for handball and basketball players', however, to a lesser extent. These athletes are required to accelerate and rapidly change direction of movement at longer distances than table tennis players (Bishop and Wright, 2006; Karcher and Buchheit, 2014). Abilities such as visual reaction time, speed, and strength are essentials of reactive agility (Horníková, Jeleň, & Zemková, 2021).

Even though most of the key performance factors can be influenced by sport-specific training, some physiological aspects of athletic performance, such as fast-twitch muscle fiber composition or maximal oxygen consumption cannot be significantly manipulated due to genetics (Tucker and Collins, 2012; Pickering and Kiely, 2017). Other factors, such as gender, playing level, players' position, and training experience are also crucial to consider while evaluating athletes' physical and perceptual-cognitive skills (Bhadu and Singh, 2016; Peña et al., 2018; Popowczak et al., 2021).

Modern assessment methods additionally permit the measurement of athletes' sensory and perceptual-cognitive functions. The question remains whether, besides conventional evaluation of speed and strength parameters, the additional testing of a sensory component of movement could more sensitively reveal within and between-group differences. Therefore, this study investigates to what extent the key performance factors differ among athletes of sports with high demands on perception and speed of decision-making. We assumed that basketball players will dominate in lower-limb explosive strength, handball players in the change of direction speed and sprint speed, and table tennis in reaction time. This may be ascribed to different sport-specific adaptations of athletes.

Methods

Participants

Total of 7 handball, 11 basketball and 15 table tennis players participated in this study. Their age, height and body mass are displayed in Table 1. The inclusion criteria were to be an active player (regularly train and play matches), to have at least 5 years of practice, to train at least 3 times per week. Exclusion criteria was to be injury free in the last 6 weeks prior to testing and take no drugs which could lead to increasing their reaction time. Goalkeepers of team sports were also excluded from this study. All participants were informed of the procedures and the main purpose of this research. The procedures were in accordance with the ethical standards on human experimentation as stated in the Helsinki Declaration.

Table 1. Age, height and body mass of handball, basketball, and table tennis players.

Players	n	Age [years]	Height [cm]	Weight [kg]
Handball	7	20.9 ± 0.5	183.3 ± 4.9	85.6 ± 8.1
Basketball	11	20.0 ± 2.0	188 ± 4.1	79.4 ± 8.9
Table Tennis	15	19.5 ± 0.8	179.4 ± 6.0	77.2 ± 6.4

Procedures

Prior to the testing, all participants performed a 10-minutes warm-up including light aerobic running and dynamic stretching exercises. Then they attended a familiar session where the testing conditions were explained, and the trial sets were carried out. First, they performed simple and choice reaction time tests using FiTRO Reaction check (FiTRONiC, Bratislava, Slovakia), and tests consisting of responses to slow and fast generating stimuli using Witty SEM (Microgate, Bolzano, Italy). Secondly, squat jump (SJ), countermovement jump (CMJ), and drop jump (DJ) were measured using OptoGait (Microgate, Bolzano, Italy). Lastly, the 505 Agility test, 5 m and 20 m sprint tests were measured by the Witty system (Microgate, Bolzano, Italy).

Simple and choice reaction time tests (SRT & CRT)

Both tests were measured by the diagnostic system FiTRO Reaction check in accordance with protocol (Zemková, 2018). The device consisted of two pressure switches connected with an interface to a computer. Participant´s task was to respond as fast as possible to one visual stimulus (simple reaction time test) by pushing the switch positioned on the table. As a stimulus, the green circle on a white background was used. In the test of choice reaction, participants had to decide and respond as fast as possible to two visual stimuli and press the corresponding switch. When the green circle appeared on the screen, they had to press the right switch and when the red cross appeared, the left switch had to be pressed. Responses were performed by both hands, which were constantly in contact with switches in order to minimize the motor component. In both tasks, two trials of 20 responses were used and the result was better mean reaction time (simple and choice) of them.

Reaction time test to slow and fast generating stimuli (SGS & FGS)

The Witty SEM device consisted of four light photocells situated in one line on a table at a distance of 10 cm from each other. Participant´s task was to respond as fast as possible with a dominant hand to photocells which lit up green. The starting position of the hand was as close

as possible the center under the photocells. These photocells were non-contact, so they didn't have to touch them. A total of 20 visual reactions (five for each photocell) in both tests were used. The only difference between two versions of tests was in generating time, as in the faster version stimuli were generated immediately after response and in the slower version with one-second delay between them.

Squat jump (SJ)

Participants performed two jumps with 15 s rest period between trials without previous countermovement. The starting position was in a semi-half squat (90° in knee position measured by a goniometer) with hands on the hips. The task was to jump as high as possible without countermovement. The result was the higher jump from these two trials.

Countermovement jump (CMJ)

Participants performed CMJ from a standing position, where they bent their knees (approx. 90°) and then immediately jumped as high as possible. They performed two jumps with 15 s rest period between them and the higher of them was recorded for further analysis.

Drop jump (DJ)

Participant´s task was to fall and rebound as fast as possible with a minimum ground contact time from a 30 cm-high box with hands placed on hips. They were asked to avoid more pronounced knee bending and kicking during the jump and land in a fully extended position without hip, knee, or ankle flexion. The system OptoGait recorded the height of a jump and ground contact time. The reactive strength index (RSI) was calculated as a ratio of the jump height and duration of contact automatically by the OptoGait software. The higher RSI of two trials was taken for further analysis.

The 505 Agility test

Participants started the test behind the start line and sprint maximally to a line marked 15 m away from the start line, place either left or right foot on this line, then turn 180° and sprint back over a length of 5 m through the finish gate. The time was measured only 5 m before and 5 m after this change of direction on the turning line. Two trials were performed (right and left turn) and better time was taken for further analysis.

5 m and 20 m sprint tests

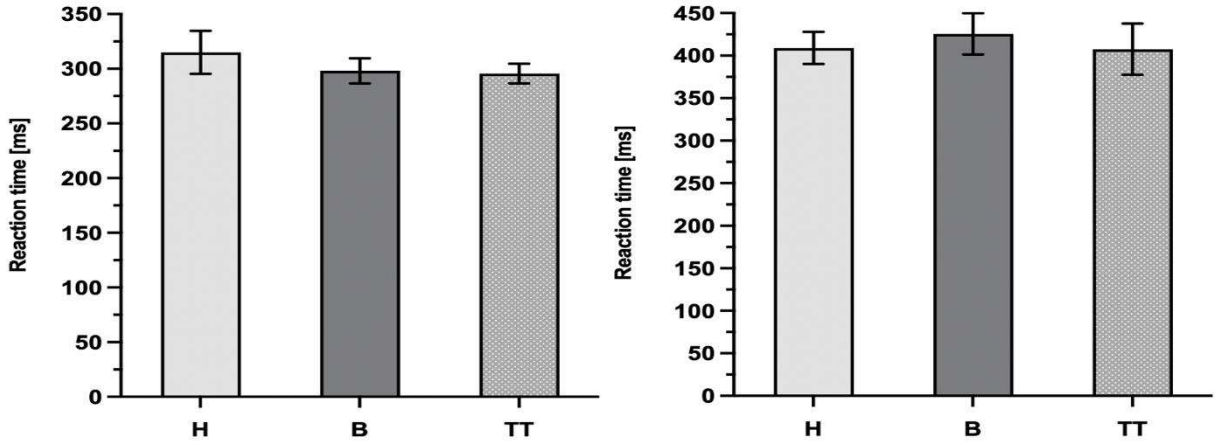
A 20-m-long linear sprint with 5 m split time was measured by the three pairs of photocells positioned at 0 m, 5 m, and 20 m. Gates were set at a width of 1.5 m and height of 1.2 m. Participant´s task was to sprint as fast as possible through each gate. They started 0.3 m behind the start line to prevent early triggering of the initial start gate. The result was a better of two trials.

Statistical analyses

All statistical analyses were computed using the statistical program SPSS for Windows (version 22.0, SPSS, Inc., Chicago, IL, USA). Descriptive statistics (mean ± SD) were calculated for all results. Prior to the data analysis, the Shapiro-Wilk test was performed for all variables to check if the data was normally distributed and then Levene's test for homogeneity of variance was used. One-way ANOVA was used to find the differences among the group of players following the Tukey HSD post hoc test. Cohen´s d was used to detect the effect size with the following interpretation: small effect ($0.2 \leq d < 0.50$), medium effect ($0.50 \leq d < 0.80$), and large effect size ($d \geq 0.80$) (Cohen 1988).

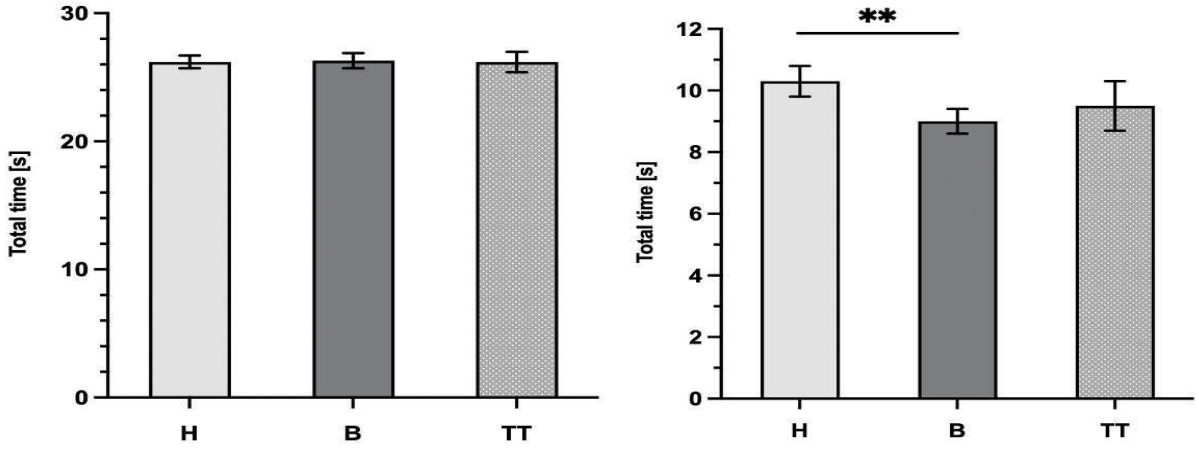
Results

Reaction time to fast generating stimuli ($F_{(2)}$ = 7.60, p = 0.002) differed significantly among handball, basketball and table tennis players. Its values were significantly shorter in basketball than in handball players (12.6 %, p = 0.001, *d* = 2.9, Fig. 2b). However, there were not significant between-group differences in other reaction time tests (Fig. 1 & 2a). Nevertheless, large effect size indicated differences in simple reaction time and reaction time to fast generating stimuli between table tennis and handball players (6.2 %, *d* = 1.3 and 7.8 %, *d* = 1.1, respectively). Table tennis players also achieved shorter choice reaction time compared to basketball players, which is corroborated by a medium effect size (4.3 %, *d* = 0.7).



(a) (b)

Figure 1. Comparison of a) Simple reaction time, b) choice reaction time among handball (H), basketball (B) and table tennis players (TT).

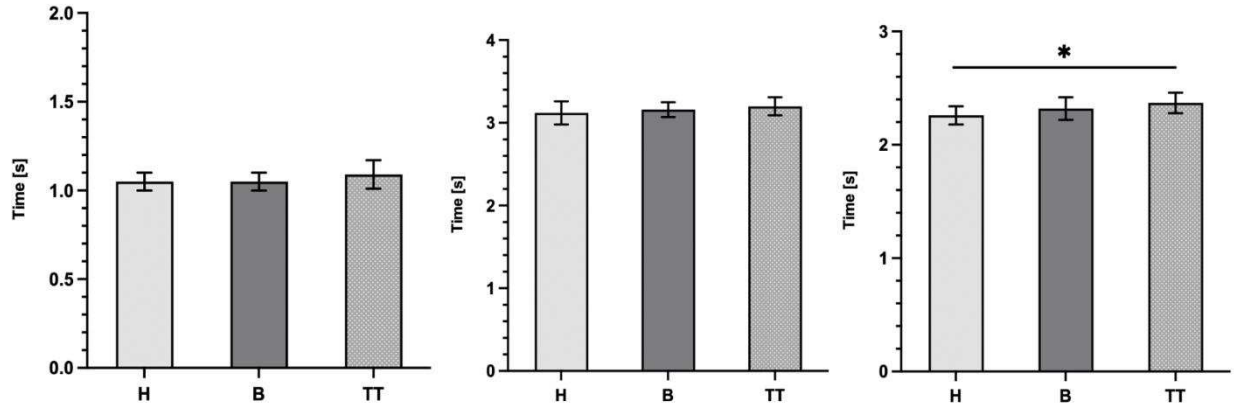


(a) (b)

*Figure 2. Comparison of total reaction time to a) slow generating stimuli, b) fast generating stimuli handball (H), basketball (B) and table tennis players (TT) (** p<0.01).*

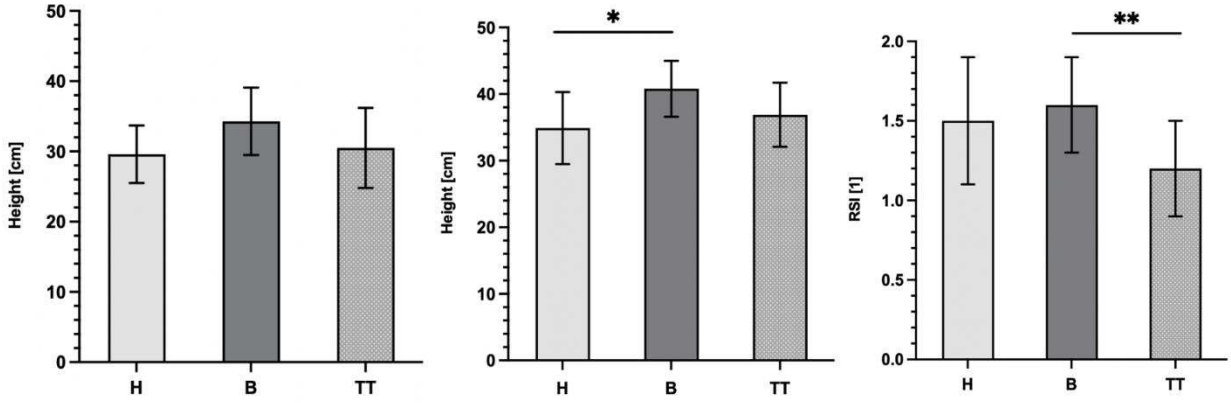
Results of speed tests are One-way ANOVA revealed significant differences in change of direction speed among handball, basketball and table tennis players ($F_{(2)}$ = 3.50, p = 0.04). Post-

hoc test showed that the time in 505 Agility test was significantly shorter in handball than in table tennis players (0.11 s, p = 0.04, 4.6 %, *d* = 1.3, Fig. 3c). Medium effect size detected shorter time in 505 Agility test in handball players than in basketball players (2.6 %, *d* = 0.7), and shorter time in 5 m and 20 m sprint than in table tennis players (2.7 %, *d* = 0.6, and 2.5 %, *d* = 0.6, respectively) (Fig. 3a & b).



a) b) c)

Figure 3. Comparison of a) 5 m sprint time, b) 20 m sprint time, c) 505 Agility time among handball (H), basketball (B) and table tennis players (TT) (p < 0.05).*



a) b) c)

*Figure 4. Comparison of a) SJ height, b) CMJ height, c) RSI in drop jump handball (H), basketball (B) and table tennis players (TT) (** p < 0.01).*

Furthermore, RSI in DJ ($F_{(2)}$ = 4.80, p = 0.02), and in CMJ height ($F_{(2)}$ = 3.47, p = 0.04) differed significantly among groups of players. More specifically, basketball players achieved significantly higher RSI than table tennis players (25 %, p = 0.01, d = 1.4, Fig. 4c) and their CMJ height was significantly higher compared to handball players (14.5 %, p = 0.05, *d* = 1.2, Fig. 4b). In addition, basketball players achieved higher SJ compared to handball and table tennis players (13.7 %, *d* = 1.0, and 11.1 %, *d* = 0.7, respectively), and higher CMJ compared to table tennis players (9.6 %, *d* = 0.9) as indicated by medium to large effect sizes.

Discussion

Taking into account the structure of performance in handball, basketball, and table tennis, it is most likely to reveal differences in sensory and motor components of athletes' performance. As shown, basketball players respond better to fast generating stimuli than handball players. They also surpass table tennis players in reactive strength and handball players in explosive strength. Handball players show superior agility performance compared to table tennis players. There was a tendency of table tennis players to perform better in simple and choice reaction time tests compared to handball and basketball players.

In regard to reaction time, basketball players achieved significantly shorter reaction time in response to fast generating stimuli compared to handball players. This can be ascribed to higher demands on responses to different visual stimuli while passing shorter distances on smaller basketball than the handball playing field. However, they did not differ in response to slow generating stimuli nor in simple and choice reaction times, which confirms that the high level of perceptual and cognitive abilities as well as the speed of response are needed for both of them (Bruce et al., 2012; Gabbett and Benton, 2009; Henry et al., 2011; Santos et al., 2016). Surprisingly, table tennis players were not significantly better than handball and basketball players, which may be the result of a long-term adaptation of cognitive perception to visual stimuli of team sport players. Nevertheless, effect sizes indicated domination of table tennis in simple and choice reaction time compared to handball and basketball players. This may be corroborated by the tendency of table tennis players to react faster to one or two visual stimuli as a long-term training adaptation to the high speed of a flying ball which improves players' ability to react very quickly (Ak and Kocak, 2010; Marinovic, Iizuka, & Freudenheim, 2004). Playing table tennis leads to improved cognitive skills overall (Hung et al., 2004; Wang, Guo, & Zhou, 2016; Walsh, 2014).

With regards to speed factors, the change of direction speed was significantly faster in handball than table tennis players. This ability is also more dominant in handball than in basketball players expressed by medium effect size. Similarly, medium effect sizes indicated better linear speed in 5 m and 20 m sprints in handball than table tennis players. These results may be assumed because these athletes are required to accelerate and rapidly change the direction of movement at longer distances than table tennis players (Bishop and Wright, 2006; Karcher and Buchheit, 2014). As assumed, long-term training and match adaptation of handball players resulted in their dominance in speed abilities compared to basketball and table tennis players. Although running speed factors are crucial also in basketball players, it must be taken into account that handball players often sprint for longer distances than basketball players due to larger playing areas. Superior sprint times of handball players support the notion that sprinting skills are crucial components of the motor skill arsenal in professional handball players (Haugen, Breitschädel, & Seiler 2019).

With regards to strength parameters, basketball players achieved significantly higher RSI compared to table tennis players and higher CMJ height compared to handball players. Similar results were found in a study of Singh et al. (2014) which have shown that male basketball players achieved better results in vertical jump tests (SJ and CMJ) as compared to male handball players. There are several explanations for these results. Firstly, basketball involves many vertical jumps with both legs in the attacking and defensive phase. This results in long-term adaptation of basketball players to specific movement activities such as vertical jumps, bounces, and rebounds. Jumps are performed with maximum vertical reflection, which is not the case in handball. The exception is when the basketball players perform a jump from the movement after the bounced ball or when performing a shot on the basket from the movement.

In these cases, they perform jumps with a stronger leg. It is similar to handball players, when taking a shot on goal from the move using a stronger leg, too. Similar to another study, it seems that a vertical single-leg countermovement jump may have been required in testing (Aksović et al., 2022). Secondly, basketball players perform up to 100 different jumps in a game (Manojlović and Erčulj, 2013). In handball, vertical jumps are crucial as well (Dello Iaconno et al., 2017; Chanev, 2021). However, this sport is characterized by a large number of horizontal displacements. Bojić et al. (2015) have shown that basketball players jumped significantly higher in vertical jump tests, whereas handball players dominated in horizontal jump tests. With regards to table tennis, in which explosiveness is also necessary (Vacenovský, 2014), jumps are not performed directly during the game. It is more likely important for starting rebounds in various directions.

Whereas differences were found in the motor (speed and strength factors) rather than in sensory components, our testing methods could be considered non-specific (i.e., no sport-specific stimuli nor typical movement patterns). Tests used in this study are standardized and very often involved in athletes' diagnostics. Therefore, more specific and sensitive tests could reveal slight differences and changes in adaptation to training among athletes more precisely. It comes also into consideration whether it would be not better to use various types of change of direction speed tests (e.g., various angles of changes in direction, longer/shorter distances with dribbling) and explosive strength tests (e. g., horizontal/vertical, one-leg jumps, lateral jumps) which could lead to significant within and between-group differences in these key factors.

The low sample size can be considered the main limitation of this study. Therefore, it is not possible to make interferences applying to the entire population of male handball, basketball, and table tennis players. Players' positions in team sports, which we did not take into account may also play a role in the obtained results. For example, guards in basketball differed from forwards and wings in handball differed from the other positions in terms of superior 10 m and 40 m sprint times (Haugen et al., 2019). Therefore, further research should consider to assess and compare the key differences in performance factors of specific positions in team sports.

Conclusion

Differences exist in key factors of performance among handball, basketball, and table tennis players which may be ascribed to their adaptation to sport-specific stimuli. Basketball players respond better to fast generating stimuli than handball players. They also surpass table tennis players in reactive strength and handball players in explosive strength. Handball players show superior agility performance compared to table tennis players. Surprisingly, table tennis players did not present significantly lower reaction time to visual stimuli compared to handball and basketball players. Nevertheless, large and medium effect sizes indicate their fastest visual reactions. It seems that tests reflecting motor skills better differentiate athletes of various specializations in comparison with tests evaluating the sensory component of their performance. Assessing perception and speed of decision-making under sport-specific conditions could contribute to reveal within and between-groups differences and perhaps also slight changes more sensitively during various training periods. This requires developing novel methods and devices for the assessment of athletes' sensory and cognitive skills to determine their key performance factors in specific sports.

Acknowledgements

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