VELOCITY AND ACCURACY AS PERFORMANCE CRITERIA FOR THREE DIFFERENT SOCCER KICKING TECHNIQUES

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Kicking velocity (KV) and kicking accuracy (KA) of 19 experienced male soccer players were examined for the full instep, the inner instep, and the side foot kick. Measurements were performed simultaneously by a radar gun (KV) and a newly introduced high-speed-video camera set-up (KA). Subjects had two different tasks: to kick as fast as possible (Max KV) and to kick as accurate as possible (Max KA) with each kicking technique. Six repetitive kicks were performed for each required condition. The full instep and the inner instep kick were faster compared to the side foot kick for both performance tasks. In contrast, the side foot kick was the more accurate technique compared to the inner instep and the full instep kick, also for both performance tasks. Kicking variability between and within subjects was generally low for KV and generally high for KA for all kicking. It is concluded that velocity control is easier to achieve than accuracy control for soccer kicks.

KEY WORDS: soccer, kicking performance, kicking velocity, kicking accuracy, variability

INTRODUCTION: The different kicking techniques in soccer are the most characteristic technical skills of the game. Especially the full instep kick has been biomechanically studied in detail defining its typical components including the foot/ball contact phase (Barfield, 1998). This phase is characterized as a mixture of an impact-like and a throwing-like movement (Tsaousidis & Zatsiorsky, 1996). Due to the relatively short contact time of about 9 ms for instep kicking (Shinkai et al., 2009), the success of the kick, ball velocity and ball accuracy, is already determined at ball impact. Generally, successful kicks need to be fast and accurate, especially when kicking on goal. This allows the goal keeper less time to react and also makes it difficult to reach the ball. Thus, KV and KA are important performance criteria for soccer kicking. Recent research showed the influence of soccer footwear on KV and KA. Astonishingly, decreased KV was found when kicking shod compared to barefoot (Sterzing & Hennig, 2008). However, for KA shod kicking increases performance compared to barefoot kicking (Hennig, Althoff & Hömme, 2009). Only few studies have investigated the general influence of different kicking techniques on these performance criteria. Side foot kicks were shown to be slower compared to full instep kicks (Levanon & Dapena, 1998; Nunome et al., 2002). Among the different instep kicking techniques the full instep kick is the fastest, followed by the inner and outer instep kicks (Neilson & Jones, 2005). Here, reduced ball velocities for the inner and outer instep kicking techniques are traded to ball spin achieved by off-centered foot/ball contact. Kicking performance studies have mainly focused on KV. One study compared KV and KA of the instep compared to the less frequently used toe kick stating the toe kick to be less precise than the instep kick at 90 % of maximum KV (Kristensen, Andersen & Sorensen, 2005). The lack of KA studies may be due to the lack of suitable and easy to use measurement procedures. One protocol was proposed by Finnoff, Newcomber and Laskowski (2002). Their approach was based on the use of carbon paper sheets attached to a wooden target board, thereby providing imprints of the ball at impact. Hennig, Althoff and Hömme (2009) determined KA by usage of a circular electronic target fixed to a wooden board. Here, the ball creates electrostatic charges that allow identifying the ball impact location relative to the board center.

The purpose of our research was to quantify KV and KA for three frequently used soccer kicking techniques. Between and within subject variability was examined for different kicking performance tasks and kicking techniques. In order to carry out this research, an innovative KA measurement procedure was introduced.

METHODS: Research was conducted on a 5 x 20 m artificial turf outdoor testing area. 19 experienced soccer players (4^{th} - 6^{th} German league, 23.7 ± 3.4 yrs, 1.80 ± 0.05 m, 74.8 ± 5.6 kg) participated in this study. After warming-up and familiarization trials, subjects performed twelve repetitive kicks with each of three kicking techniques, full instep, inner instep and side foot. For each kicking technique, subjects had to execute two different performance tasks. Six kicks were meant to maximize ball velocity (Max KV) and the remaining six kicks were meant to maximize ball accuracy (Max KA). This resulted in altogether 36 single kicks per subject. Different performance tasks and kicking techniques were randomized between subjects. For Max KV, KV was the main variable whereas KA was regarded as dependent variable and vice versa for Max KA. All kicks were performed with a stationary ball from a distance of 6 m to the target goal construction in subjects' own soccer shoes.

Kicking was directed towards a bull's eye target (1 m height) in the middle of a 5 x 2 m goal construction. The goal construction was covered with a spanned, slightly transparent sheet that was hanging down from the cross-bar. KV and KA were recorded simultaneously for identical kicks. KV was measured by usage of a *Stalker Pro* radar gun (*Applied Concepts Inc., TX, USA*) positioned behind the goal, according to Sterzing and Hennig (2008). KA measurements were performed by recording the ball impact on the sheet by usage of a high-speed-video camera at 200 Hz (*CMOS Camera, HCC-1000, VDS Vosskühler, Germany*) also positioned behind the goal construction. KA was measured as the distance from bull's eye to ball impact location of the ball center. Absolute distance was determined with *MaxTRAQ 2.06* software (*Innovisions Systems, MI, USA*).

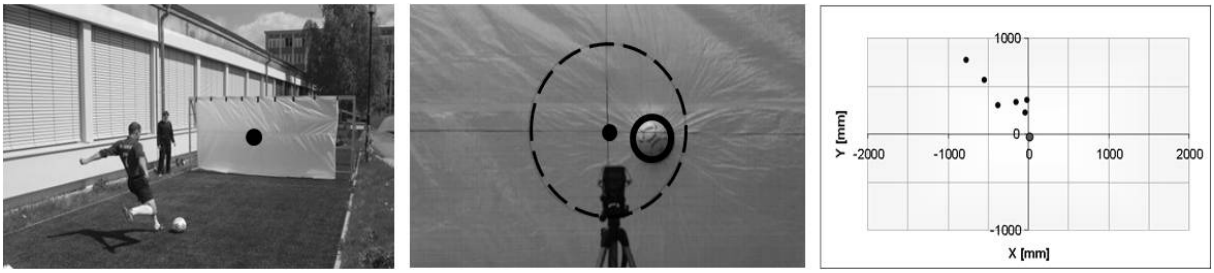

Figure 1: Experimental set-up (left), ball impact relative to bull's eye captured by high-speed-video (middle), visualization of KA for six kicks relative to bull's eye (right)

Means, standard deviations (SD) and coefficients of variability (CoV) for KV and KA for the two performance tasks applied to the three kicking techniques were calculated across all subjects. Repeated measures ANOVA and Bonferroni post-hoc tests were utilized to compare KV and KA between kicking techniques for both tasks. Additionally, respective effect sizes based on partial eta squared (eta^2) were calculated. RMSE of KV and KA were performed to assess the relation of intraindividual and interindividual variability of kicks for performance tasks and kicking techniques. Also, the mean of within subjects $CoV_{6\ kicks}$ was calculated across all subjects. Thereby, $CoV_{6\ kicks}$ refers to the variability of the six repetitive kicks for each performance task/kicking technique.

RESULTS AND DISCUSSION: Independent of the required performance task, KV was significantly influenced by the different kicking techniques (Max KV: $p<0.01$, eta^2: 0.88; Max KA: $p<0.01$, eta^2: 0.43) (Figure 2, Table 1). Bonferroni post-hoc tests revealed significant differences ($p<0.01$) between side foot and both instep kicks but not between the two instep kicking techniques. In contrast but also independent of the required performance task, KA was generally higher for the side foot kick compared to the inner instep and the full instep kick (Max KV: $p<0.01$, eta^2: 0.37; Max KA: $p<0.01$, eta^2: 0.56) (Figure 2, Table 2). However, Bonferroni post-hoc tests revealed significant differences for Max KV only between side foot and full instep kicks and for Max KA between side foot and both instep kicks. As expected, subjects kicked with sub maximal velocity in all different kicking techniques (full instep: 85 %, inner instep: 82 %, side foot: 86 %) when KA was required. Thereby, the presented percentages have to be regarded as specific for the given study design requiring kicks over a

distance of only 6 m. These KV percentages might be increased when kicking over a longer distance is required.

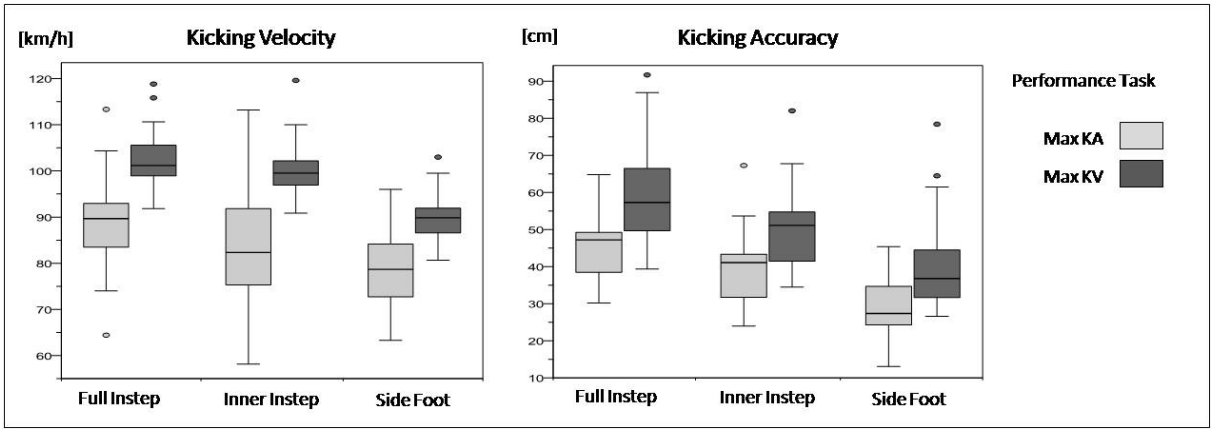

Figure 2: Kicking velocity [km/h] and kicking accuracy [cm]

CoV between subjects revealed that KV was the more homogenous variable compared to KA, regardless of the required performance task. The lowest CoV were present when subjects had to kick as fast as possible (Table 1 & 2). Mean within subject $CoV_{6\ kicks}$ showed that kicks were performed with strikingly homogenous KV (Table 1) for all required performance tasks. This is not astonishing when subjects were required to kick as fast as possible. However, when required to kick as accurate as possible individual subject's kicking velocity was similarly homogenous. This indicates that soccer players use a stable KV strategy when required to perform precision kicks. In contrast, individual KA variability was considerably high for all required performance tasks (Table 2).

Table 1: Kicking Velocity [km/h]

Technique	Task	n	Range	Min	Max	Mean	SD	COV	RMSE	$CoV_{6\ kicks}$
Full Instep	Max KV	19	27,00	91,83	118,83	103,16	6,51	0,063	1,49	0,034
Full Instep	Max KA	19	48,90	64,43	113,33	87,76	11,17	0,127	2,56	0,044
Inner Instep	Max KV	19	28,77	90,83	119,60	100,75	6,90	0,068	1,58	0,032
Inner Instep	Max KA	19	55,03	58,17	113,20	82,99	14,45	0,174	3,32	0,052
Side Foot	Max KV	19	22,33	80,67	103,00	89,79	5,65	0,063	1,30	0,029
Side Foot	Max KA	19	45,83	50,17	96,00	77,38	11,27	0,146	2,59	0,047

Table 2: Kicking Accuracy [cm]

Technique	Task	n	Range	Min	Max	Mean	SD	COV	RMSE	$CoV_{6\ kicks}$
Full Instep	Max KV	19	52,36	39,33	91,69	59,51	14,04	0,236	3,22	0,633
Full Instep	Max KA	19	34,64	30,16	64,80	45,93	9,90	0,216	2,27	0,550
Inner Instep	Max KV	19	47,54	34,48	82,02	50,85	12,29	0,242	2,82	0,477
Inner Instep	Max KA	19	43,29	23,98	67,27	39,65	11,02	0,278	2,53	0,613
Side Foot	Max KV	19	51,81	26,58	78,39	40,53	14,38	0,355	3,30	0,573
Side Foot	Max KA	19	32,34	13,05	45,38	28,83	7,90	0,274	1,81	0,572

CONCLUSION: A new protocol for simultaneous KV and KA measurements of soccer kicks was introduced and shown to be suited and practicable for the determination of kicking performance. This allowed carrying out a first soccer kicking performance study that comprehensively investigated the relationship of KV and KA for three different kicking techniques. Generally, our KV results of the examined techniques are in line with the

literature knowledge which reported the full instep kick to be the fastest kicking technique followed by inner instep and side foot kicks (Levanon & Dapena, 1998; Nunome et al., 2002; Neilson & Jones, 2005). Previous knowledge was enhanced by quantification of KA of the different soccer techniques, stating the side foot kick to be most accurate followed by the inner instep and full instep kicking techniques. However, in soccer, kicking requirements differ with respect to the game situation, giving priority to concentrate either on KV or KA. In this study, soccer players, on average, reduced their KV to 82 - 86 % of their maximum KV for a given kicking technique when KA was the ultimate priority. It seems that KV, in contrast to KA, can be more easily tuned by soccer players. The fact that subjects had considerable low individual KV variability during all different performance tasks of this study is interesting. It shows that experienced soccer players have developed a solid motor performance pattern, which features a stable KV, when executing a given kicking task. In contrast, KA compared to KV must be regarded the much more variable aspect, also when referring to within subjects analysis. Thus, although when highly standardized kicking tasks are required to be performed by the players, a solid motor performance pattern does not guarantee KA success.

The results of this research call for a follow-up study which should aim towards identification of the biomechanical mechanisms that are responsible for the observed findings. Therefore, further research should investigate full 3D kinematics of the kicking tasks analyzed in the present study in order to link performance criteria to variation in skill execution. This might help to improve soccer kicking skills and consequently playing performance of players. Also, with a viable protocol to assess performance criteria of soccer kicking now available, one should aim to examine specific player groups, e.g. of different playing level, age and gender.

Furthermore, the general relationship of ball velocity and ball accuracy is of inherent interest in numerous types of ball/team/ sports. Thus, sports, which feature different ball propulsion characteristics, e.g. handball, volleyball, tennis or field hockey should be investigated too.

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