BIOMECHANICAL PROFILE OF SOCCER GOALKEEPERS

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Although the soccer goalkeeper often plays a decisive role in the outcome of a match, research on the goalkeeper's actions or the qualities required of a top class goalkeeper is scarce. With this study we attempted to define a biomechanical profile of the goalkeeper. We tested whether the skill level of 6 goalkeepers, determined by the league they played in, correlated with a number of biomechanical tests. The tests were devised as standardized measurements of typical goalkeeper actions; they comprised various jumps, a short sprint and a leg strength measurement. We found no correlation between the goalkeepers' skill level and their score in any of the tests. Thus, with reservation for the limited number of subjects, we conclude that the measured biomechanical parameters are of minor importance compared to skills as tactical understanding, perception and anticipation.

KEY WORDS: soccer, goalkeeper

INTRODUCTION: Soccer is a popular and well-known game worldwide with numerous matches of different levels played every day. People are fascinated by the unpredictable game, which, on occasions, can be determined in seconds by extraordinary moves or fatal mistakes. As the last line of defense, the goalkeeper is often directly involved in these decisive moments. Thus, it seems relevant to investigate the goalkeeper's play in greater detail. Although an extensive amount of soccer research has been published, e.g. in conjunction with the scientific congress on the various styles of football held every four years (Reilly *et al.*, 1997), the vast majority is of physiological nature, and hence more applicable to the field players. The goalkeeper's actions are typically very short term, explosive type and technically demanding, i.e. more biomechanical in nature (Bangsbo, 1993). However, in a review Lees & Nolan (1998) stated that the biomechanics literature only contained one study on goalkeepers (Suzuki *et al.*, 1988). In this study on the goalkeeper's diving motion the authors found that two high level goalkeepers could propel their center of gravity with higher velocity and in a more direct trajectory towards the ball than two lower level goalkeepers. In the present study we employed a broader range of tests, including a diving motion similar to the one investigated by Suzuki *et al.* (1988) as well as three other jumping motions, a short sprint and a leg strength measurement. We speculated that a correlation between the goalkeepers' skill level, determined by the league they played in, and their test scores would indicate that the biomechanical parameters underlying the tests (speed, jumping ability and strength) are important factors for a goalkeeper's match performance. Given any such correlations, we would expect that a performance increase in the test scores would lead to a higher skill level as goalkeeper. This could be used directly in the training of goalkeepers. For example, if leg strength correlates with skill level, we would expect that an increase in leg strength would lead to better match performance, and hence urge soccer coaches to emphasize strength training for their goalkeepers. Thus, the purpose of this study was to investigate whether the skill level of soccer goalkeepers correlates with a series of standardized biomechanical tests.

METHODS: Six male goalkeepers of varying skill levels, from the Danish series 5 (lowest) to the Danish 2nd division (highest), participated as subjects (Table 1). They were tested during the tournament period of the Danish soccer season and hence considered to be in optimum shape. After warming up, the subjects were taken through a test battery comprising assessment of 6 biomechanical parameters considered important for the goalkeeper's match performance: Squat jump, counter movement jump, reaction jump, maximal horizontal jump, 10 m sprint and leg strength, performed in above order. Each activity, with the exception of the leg strength measurement, was captured with a high-speed digital video camera (JVC DV 9800) operating at 120 frames per second. The camera was placed 1.32 m above floor level 9.48 m from where

Table 1. Subject characteristics.

Subject	AT	BH	DB	MG	KB	MO
Skill level	series 5	series 4	series 3/1	series 1/DS	2nd division	2nd division
Height (cm)	194	178	181	177	183	188
Body mass (kg)	89	73	75	71	84	80
Age (years)	20	32	25	20	26	27

Note. The Danish soccer leagues comprise series 6 (lowest), series 5-1, regional series, national series (DS = Danmarks-Serien), 3rd division, 2nd division, 1st division, and the Super League (highest). During the season where the tests were conducted subject DB played matches on a series 3 and a series 1 team, and subject MG played matches on a series 1 and a national series (DS) team.

the subject performed the jumps. During squat jumps and counter movement jumps the subject wore a reflective marker over the right hip joint. The video captures were transferred to a PC for subsequent analysis with the APAS video analysis system (Ariel Dynamics Inc., San Diego, U.S.A.).

Squat jump: The subject was filmed from his right side. The start position for the jump was with the feet placed parallel side by side, the knees flexed to a 90° angle and the hands held on the hips. From this position the subject executed a maximal vertical jump without moving the hands. The jump height (test parameter) was determined from the video capture as the vertical difference between the hip marker's highest position during the jump and its position when the subject stood relaxed with straight legs. Each subject performed 5 jumps.

Counter movement jump: The subject was filmed from his right side. The start position for the jump was with parallel feet, straight knees and the hands held on the hips. From this position the subject executed a maximal counter movement jump without moving the hands. The subject could freely choose range and velocity of the downward movement as well as pause duration at the crouched position. The jump height (test parameter) was determined by the same method as for the squat jump. Each subject performed 5 jumps.

Reaction jump: The subject was filmed facing the camera. On each side of the subject a soccer ball was suspended 1.5 m above the floor, 2.5 m from the subject's start position, which was indicated by a mark on the floor midway between the suspended balls. The subject was required to stand with the vertical centerline of the body over this mark, but was otherwise free to adopt the start position he preferred. Two small lamps were placed 0.30 m apart between the subject and the camera. Depending on which of these lamps the investigators turned on, the subject would jump and make contact with either the left or the right ball as fast as possible. Cushioning mats were placed on the floor on both side of the subject. The reaction time (test parameter) was determined from the video capture as the elapsed time from when the lamp lid up to when the ball moved. Each subject performed 3 jumps to each side in random order, without being informed about the number of jumps beforehand.

Maximal horizontal jump: The subject was filmed facing the camera. On the subject's preferred side a soccer ball was suspended 0.30 m above the floor, 3.69 m from the mark indicating the subject's start position. The remaining start position details were similar to those in the squat jump. A cushioning mat was placed on the floor on the same side of the subject as the ball. From the start position the subject would jump sideways trying to make contact with the ball. The subject was allowed to take a short side step towards the ball with the foot closest to the ball just prior to the jump. After each successful attempt the ball was moved a fixed distance (0.13 m) further away from the start position until the subject was unable to reach the ball. The maximal horizontal jumping length (test parameter) was determined as the distance from the start position mark to the ball in the last successful attempt.

10 m sprint: The subject performed a 10 m sprint run on a wooden floor from a standing start. In the start position the subject stood 10 m to the left of the camera with the feet placed side by side, facing the running direction. The investigators signaled start by turning on a small lamp placed on a post in front of the camera. The running time (test parameter) was determined from the video capture as the elapsed time from when the lamp lid up to when the subject passed an imaginary line between the camera and the lamppost. Each subject performed 3 sprints.

Leg strength: As an indicator of leg strength the subject performed a one repetition maximum (1RM) concentric squat lifting a barbell on the shoulders behind the neck. The subject started by assuming a position with the feet placed parallel side by side and the knees flexed to a 90° angle. Prior to this, a set of pins in the squat rack had been adjusted so the barbell could rest in the rack, slightly touching the subject's shoulders. From this position the subject performed a concentric hip and knee extension to standing upright position, where the barbell was put back into another previously adjusted set of pins in the squat rack. Each subject started with 60 kg. After each successful attempt the weight was increased in 20 kg steps up to a total mass of 100 kg, thereafter in 10 kg steps. Leg strength was determined as mass lifted (test parameter) in the last successful attempt.

Table 2. Test results.

Subject	AT	BH	DB	MG	KB	MO	ρ
Squat jump (m)†	0.526	0.476	0.469	0.485	0.398	0.416	-0.786
Counter movement jump (m)†	0.530	0.511	0.501	0.474	0.458	0.455	-0.957
Reaction jump left (ms)‡	1153	1083	1047	1150	1136	1061	0.329
Reaction jump right (ms)‡	1261	1197	1097	1208	1083	1150	0.671
Reaction jump average (ms)‡	1207	1140	1072	1179	1110	1106	0.529
Maximal horizontal jump (m)†	3.95	3.95	3.82	3.95	3.95	4.34	-0.171
10 m sprint (ms)‡	2381	2497	2478	2514	2422	2503	-0.386
Leg strength (kg)†	130	120	100	110	140	110	-0.014
Leg strength / body mass (kg/kg)†	1.46	1.64	1.33	1.55	1.67	1.38	0.157

Note. †Best attempt. ‡Average of all attempts. ρ: Spearman's rank order correlation coefficient.

RESULTS: Table 2 presents the results from the 6 tests; the subjects are listed according to skill level from lowest to highest (as in Table 1). The last column shows Spearman's rank order correlation coefficient for each test parameter vs. skill level (due to the low subject-to-test parameter ratio we abstain from multiple correlation calculations). The correlation coefficients are either negative, i.e. subjects with higher skill level have lower test score, or too low to be statistically significant at 10% level of confidence. The only parameters showing a slight tendency are the reaction jumps, which subsequently have been singled out from the table and presented graphically in Fig. 1; it seems that higher skill level is characterized by faster (shorter) reaction time, but the correlation is weak (not significant). As the skill levels of our subjects fell naturally into three groups of two (see Table 1), we present the grouped reaction jump results in Fig. 2. Presented this way, the tendency that goalkeepers with higher skill level have faster reaction time becomes more obvious.

Several test parameters are mutually correlated (values in parentheses are Pearson's correlation coefficient): Leg strength vs. 10 m sprint time (-0.726), squat jump vs. counter movement jump (0.866), reaction jump left vs. reaction jump right (0.488). These correlations were expected and indicate the validity of the measurements, but have no importance with respect to the purpose of the present study.

DISCUSSION: Biomechanical data on soccer goalkeepers are scarce (Lees & Nolan, 1998), so to ease comparison with future studies we have described our test methods in rather elaborate detail. When choosing the tests for our study we considered this comparison issue as well as activity analyses of goalkeepers from the literature. Suzuki *et al.* (1988) stated that side jump (dive) was the most used technique by the goalkeeper, while Thomassen (2000), in an extensive analysis of 21 goalkeepers' activities in 12 matches, found that the goalkeeper reacted with a side jump in approximately one third of the situations where the ball was played towards him; of these almost 60% were decisive – the opposing team scored. Hence, we

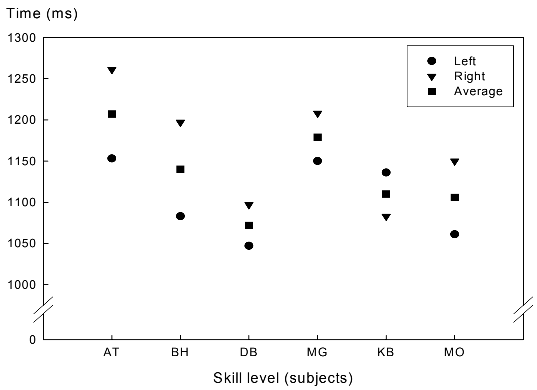

Figure 1. Reaction jumps.

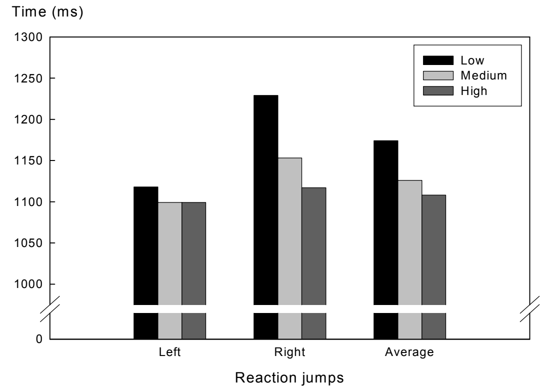

Figure 2. Reaction jumps grouped into low, medium and high skill level.

included two side jump tests where reaction time and jumping ability were measured. Our reaction jump test was deliberately designed similarly to the one used by Suzuki *et al.* (1988), i.e. balls suspended the same distance from the start position, and jump side instruction given by a light signal. Suzuki *et al.* (1988) found that two upper class goalkeepers could propel their center of gravity with greater velocity towards the ball than two lower class goalkeepers. Assuming that higher velocity jumps give shorter reaction time (from light signal to ball contact) our grouped results (Fig. 2) corroborate the findings by Suzuki *et al.* (1988).

Thomassen (2000) stated that vertical jumps seldom occur in decisive situations, but he speculated that good vertical jumping ability might allow the goalkeeper to interfere more frequently in the goal field, e.g. in situations where he would otherwise leave high balls to be headed by field players. This could indirectly affect his skill level; hence we included two vertical jumps in our tests (squat jump and counter movement jump). However, although the subjects expectedly jumped higher with a counter movement (Fleck & Kramer, 1997), their vertical jumping ability was not significantly correlated to their skill level.

The leg strength test was included because we expected leg strength to influence jumping and sprinting performance, but although we did find mutual correlations between these parameters, we did not find a significant correlation between leg strength and skill level.

Reilly & Bangsbo (1998) reported that the goalkeeper on average performs 7 sprints in a match, while Thomassen (2000) reported 4 sprints, of which 41.2% occurred in decisive situations. Thus, we included a 10 m sprint test, but found no significant correlation with skill level. This contrasted Kollath & Quade (1993) who found that professionals sprint faster than amateurs. However, it was unclear whether that study included goalkeepers, and their subjects furthermore started the sprint on their own initiative, which makes comparison to our study difficult, as we used an external start signal, which caused reaction time to be included.

Finally, we recognize that our use of league to rank skill level poses a validity problem, which is unfortunate, since the entire study is based on this ranking. Until a better ranking method becomes available, future studies should reduce this problem by including more subjects.

CONCLUSION: Since we could not establish any significant correlations between skill level and the biomechanical parameters we tested, we cannot say anything about the skills that define a good goalkeeper. On the other hand, due to the low number of subjects and the validity problem with the skill level ranking, we will not declare that the tested parameters are without importance either. Although it could be imagined that skill level is determined by a totally different set of biomechanical parameters, we doubt that this is the case and speculate that a goalkeeper’s skill level is determined by more elusive factors such as tactical understanding, placing, perception and anticipation. If this is the case, goalkeepers’ training should focus more on complex, real play like situations and less on specific jumps, etc. In popular words: The good goalkeeper never puts himself in a situation where he has to jump!

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