Biomechanomathematical Based Model: A Guide for Soccer Goalies

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Tracing the World Cup and Olympic soccer Championships shows that the top corners of the goal are very vulnerable areas. A Personal interview with ten elite goalies confirmed the issue. On the other hand these observations are based on objective rationale. To reach a top corner from the middle line of the goal the goalie needs to move diagonally, therefore the initial take off will come from the closest leg to the direction of the dive. Further thrust will come from the other leg (Tindall,1982). Mechnically speaking the diagonal movement leads to a resolution of impulse into two components which do not give him the chane to utilize his full potential in achieving a high flight height to reach the top corner while being resisted by gravity. It is also a geometrical fact that the top corners are the farthest points if the goalie stands at the mid-line of the goal as he normally does.

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The practical solution of this problem implies performance of some side steps toward the desired corner before executing the take off. If such side displacement is not enough he will not reach the top corner. And if the displacement is more than enough this means the goalie has wasted some time and might not stop the ball if even he reached the top corner. This means that the goalie is facing what could be considered as an optimization problem.

Reviewing the available literature (Gibbon & Cartwight,1981; Hughes 1980; Tindalll, 1982) shows a shortage of specific knowledge concerning this problem. On other words the determination of the side stepping distance is still matter of trail and error sort of practice which wastes time and effort.

It is the aim of the present work to try to find a practical solution based on a biomechanomathematical model which takes into consideration the physical and morphological capabilities of the goalie.

Methods

The model persented is appendix (1) was used to handle the considered motor task.

Based on the model, the leg power in vertical and side movements, range of motion of shoulder abduction, and hands-up stature are adopted as the main effecting factors on the considered motor task.

The following measurements were conducted on the ten goalies who served as a sample for the study.

1) Leg power

a) Vettical jump: a modified vertical jump was developed to permit the goalie to put a mark with both hands in the frontal plane.

b) Side stepping: time of side stepping a distance of 12 ft. (equal to the distance from the middle of the goal to the post) was measured to

The nearest 1/100 sec. This test is modified from the side stepping test of the North Carolina Motor Fitness Battery (1977).

2) Range of motion : shoulder abduction was measured with a goniometer (TEC. Clifton, N.J.).

3) Hands-up stature: was measured with an anthropometer.

The collected data were treated statistically and fed into equation 2 through a computer program to extract the data in a practical form.

As a final stage of the study the goalies of the sample were asked to use athe mechanical advice in a practical situation using skillful soccer shooters to check the validity of the results.

Results and Discussion

The basic characteristics of the sample as measured by the considerd tests are listed in Table1.

Applying pythagorean law to calculate the distance from the standing mid-point of the goalie to the top corner (fig1) it was found to be 14.420 ft. The performance of the goalies in the vertical jump table (1) shows that no goalie can achieve this distance even vertically. For this reason the goalie has to move horizontally before he jumps in order to shorten the distance between the point of take off and the top corner to be reached. However, this side distance is to be estimated by the goalie by trail and error. Both under and over estimates have their disadvantages. If he under estimates he cannot reach the corner and if he over estimates it will waste the time available especially as side stepping is not a very fast movement (8.22 ft. /sec as calculated from the data of the side-stepping test)

Table 1. Means and standard deviation of the measured variables for the sample of the study

Veriable	Mean	S.D.
Vertical Jump (ft.) (V.J.)	2.3	0.3
Side Stepping (sec) (S.S).	1.46	0.23
Shoulder abduction (deg) (S.A.)	180	0.00
Hands-up Stature (ft.) (H.U.S.)	7.62	1.20

It is the aim of equation 2 to guide the goalie to the proper location of take off in terms of the horizontal distance (S) he has to move from the mid-point with respect to his H.U.S. and V.J.

Equation (2) could be mathematically verified by subtituting (r) as 8 ft., i.e. the highest point the goalie can reach from the ground (H.U.S.+V.J.) is equal to the height of the bar. This substitution gives (S) equal to 12 ft. This means the goalie in this case has to move exactly to the post before take off which is practically true. The model could be also graphicly verfied However, when the results generated by equation (2) were applied to thesample of the study, the values of (S) appear to be slightly under estimated and that could be attributed to the decrease in thrust when it is performed sideward. It was found that a correction of 1.0% of (S) is needed for a safer situation especially at the lower limits of (S) (S<6 ft.). This correction takes into account the preference of one side over the other for most of the goalies.

The kinematic segment provides a further use for the model. Based on the laws of free falling bodies which control the movement of the goalie during the airborne phase, the flight time could be predicted by equation (4) on condition that the top corner is the top of the trajectory. Such information could be beneficial to the shooter because if he knows the projection velocity he can develop to the ball, he can estimate with acceptable accuracy the critical distance from the top corner and where he shoots from while the goalie has the least chance to hit the ball. In Other words, the distance which can be covered by the ball in a time less than the time available for the goalie to reach the top corner, That distance could be safely predicted by applying equation (5) keeping in mind that in addition to the airborne time which is calculated by equation (4) there are the response time (Jensen, Fisher 1979) and the time consumed in side-stepping. A practical situation has proved the validity of equation (5).

Regarding the tests and measurements used in this work it could be recommended to depend on the maximum height reached in the vertical jump measured from the ground as a total indicator for the three separate measures named V.I., H.U.S., and /A.A. since these three factors are determinates of performance of jump and reach. That measure is used in building up Appendix 1 which constitutes the proposed guide for the goalie concerning the side distance to be moved with regard to the maximum height reached on the vertical jump measured from the ground.

Conclusion

On the basis of the achieved results, the data represented in appendix (2) could be safely recommanded in estimating the proper side stepping distance before jumping to over the top corner.

References:

Gibbon, A. and Cartwright, John: Teaching Soccer. Bell and Hyman, London, 1980, P.130.

Hughes, C.: Soccer Tactics and Skills. British Broadasting Corporation, London, 1980, P.170.

Tindall, R.: Soccer Fundamentals. David and Charles, London, 1982, P.24.

Jensen, C.R. and Fisher,A.: Scientific Basis of Athletic Conditioning. 2nd ed. Lea & Febiger, Philadelphia, 1979, P. 193.

$r = I + j$

I = Hands up Structure

j = Height of Vertical Jump

d = Distance to cover

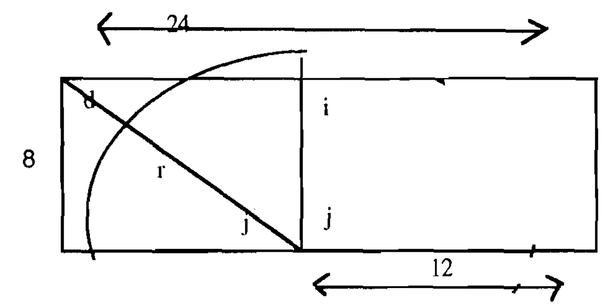

fig. 1.

As shown in Fig. 1, the Goalie will not be able to reach the corner from the centre position of the Goal.

Assume the Goalie moves horizontally a distance of s ft in the direction of the required corner, as shown in Fig. 2, then.

s = Critical side stepping Distance.

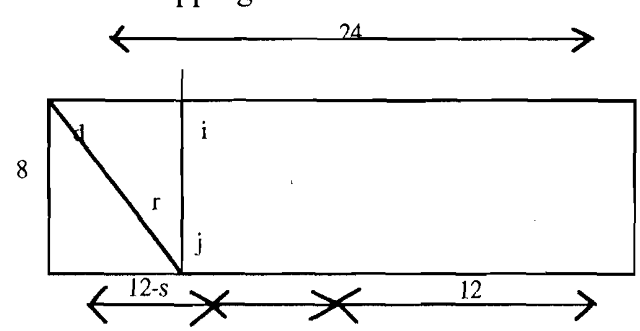

fig. 2.

$(d + r)^2 = 8^2 + (12\text{-}s)^2 \qquad O< s < 12$

In opitimal condition, d= O

$8^2 + (12\text{-}s)^2 = (r)^2$

$s^2 - 24s + (208\text{-}r2) = O$ .... (1)

$$s = \frac{24 \pm \sqrt{(24)^2 - 4(208 - r^2)}}{2}$$

$s = 12 - \sqrt{r^2 - 64}$ .... (2)

Given d = O,

$r = \sqrt{8 + (12\text{-}s)^2} = i+j$

$h = j^* \sin q \qquad = j^* 8/r.$

Since j= r-1, $\qquad h = (r - 1)^* 8/r$ .... (3)

<u>Kinematic Segment</u>

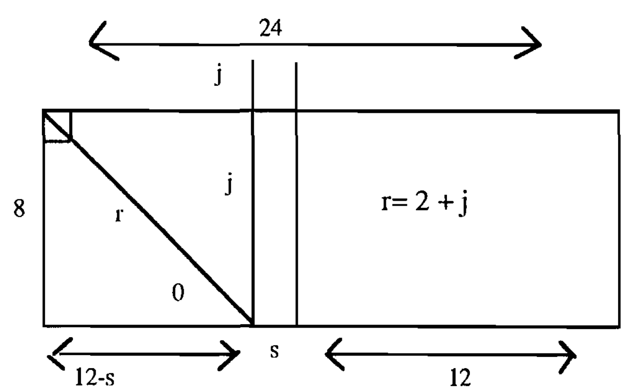

Fig.3

A^{th} max, $v = O$,

$$u_y = \sqrt{2gh}$$

$$= \sqrt{\frac{2 * 32 * 8(r-1)}{r}}$$

$$= 16\sqrt{\frac{2(r-1)}{r}}$$

$$= \frac{u_y}{g} = \frac{16\sqrt{\frac{2(r-1)}{r}}}{32}$$

$$= 0.5\sqrt{\frac{2(r-1)}{r}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Implication For Shooting Conditions

If:

t_g = Critical time for Goalie to reach top Corner O

t_b = Time for Ball to reach O

Then:

To hit the Corner $t_g < t_b$.

Solving for tb

$h = u_y * tb - 16\ tb^2$.

When h = 8 Ft., we have

$$16\ tb^2 - uy * tb - 8 = O$$

and hence

$$tb = \frac{uy + \sqrt{(uy)^2 - 512}}{32}$$

if $h \leq h_{max}$

$$R = tb2 * uy * \cos q.$$

This means the ball could be shooted from a cicumferece of quarter of a circle its raduis is (R) and its centre is considered goal post

Where;

$$R = \frac{u * \sin q \pm \sqrt{(u * \sin q)^2 - 512}}{32} * u * \cos q \quad ....(5)$$

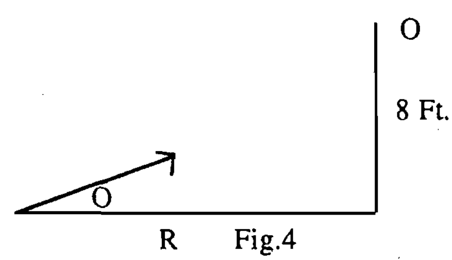

Fig.4

APENDIX (2) SIDE DISTANCE FOR HEIGHT OF JUMP AND REACH (CEN.)

J. HEIGHT	S. DISTANCE	J. HEIGHT	S. DISTANC
270	260	310	182
271	258	311	180
272	255	312	179
273	253	313	177
274	250	314	176
275	248	315	174
276	246	316	172
277	244	317	171
278	242	318	169
279	239	319	168
280	237	320	166
281	235	321	164
282	233	322	163
283	231	323	161
284	229	324	160
285	227	325	158
286	225	326	157
287	223	327	155
288	221	328	154
289	219	329	152
290	217	330	151
291	215	331	149
292	214	332	148
293	212	333	146
294	210	334	145
295	208	335	143
296	206	336	142
297	204	337	140
298	203	338	139
299	201	339	137
300	199	340	136

SIDE DISTANCE IS CORRECTED FOR 1% ERROR AND APROXIMATED TO THENEAREST INT