BIOMECHANICAL COMPARISON OF THE STANDARD AND HANDSPRING SOCCER THROW-IN

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The rules of play (3) restrict the variability in technique used for the throw-in. They define the location and method for the throw-in. However, even with these restrictions, considerable variability exists in this important skill. Differences are evident in the approach (a run followed by a hop or no approach), feet position at release (side straddle or staggard straddle), and technique (standard or handspring).

In the past, the throw-in was primarily used as a method of restarting play. More recently, there has been greater emphasis on throw-ins to project the ball long distances. This is especially true when the throw-in is taken near an opponent's goal line. Under these conditions, a long throw-in can be as effective as a corner kick.

A search of the literature has revealed only a few studies (1,5,6,7) which have investigated biomechanical perfomance parameters associated with the soccer throw-in. This is somewhat surprising because of the international prestige and popularity of soccer. Kline (5) studied the staggered stance throw-in which incorporated a running approach. His subject was a highly skilled university soccer player who was recognized for his ability to execute long throw-ins. The distance components of the approach, height of ball release, angle of ball projection, velocity of ball projection, time from release to target, spin of the ball, and general body mechanics were studied. He concluded that the approach momentum, transfer of body weight in the last stride, locking of the knee of the stride leg just prior to release, and a sequencing of trunk and upper extremity angular velocities were important factors in achieving a desired flat trajectory with maximum speed of ball projection. Levendusky, Clinger, Miller, and Armstrong (7) also studied the running approach, staggard stance throw-in. Their subjects were 12 varsity NCAA Division II soccer players. The kinematic parameters that they investigated were segmental angular velocities of the upper body and projectile motion factors. The results of their study are generally in accord with those reported by Kline (5). In addition, fore and aft ground reaction forces, experienced at the stride foot, support the concept that extension of the stride leg, when the stride foot is in contact with the ground, assists to transfer the body's approach velocity into increased angular momentum in the upper extremity. Chang (1) made comparisons among four different throw-in techniques: 1) the standing throw-in with feet in a side straddle, 2) the stride throw-in without a running approach, 3) the stride throw-in with a running approach, and 4) the handspring throw-in with a running approach. All four techniques were performed by the same subject, who was described as an experienced soccer player. Variables associated with the body (height, vertical velocity, and horizontal velocity of the center of gravity; angular velocity and momentum; and moment of inertia) and the ball at release (angle, velocity, height, and projectile range) were investigated by Chang. He reported that, at ball release, the horizontal velocity of the center of gravity was greatest for the handspring throw-in, but the height of the center of gravity was least when compared to the three other techniques. The angle of projection and the resultant velocity also favored the handspring throw-in if maximum projectile range was desirable. Chang concluded that the handspring throw-in is potentially a superior technique for maximum displacement of the ball. The present study was conducted in order to document selected biomechanical parameters associated with the performance of the standard and handspring throw-in techniques used in soccer.

PROCEDURES

Subjects

Two Michigan Class "A" high school (enrollment greater than 1150 students) male soccer players were the subjects for this study. One subject (Subject 1) was selected for his unique ability to execute a handspring throw-in. It should be noted that he was also on his high school gymnastics team. In the State High School Gymnastics Championships, he finished second in both the high bar and vault competition and sixth in the floor exercise competition. The other subject (Subject 2) was selected because he could project the ball, with a standard throw-in, farther than his teammates according to his high school coach.

Data Collection

The experimental setting consisted of an outside field space. Two lines were marked on the field (Fig. 1). One chalk line functioned as a touch line (restraining line). The target line consisted of a tape measure positioned perpendicular to the touch line with its zero measure at the intersection of these two lines. Subjects were instructed to perform each throw-in with emphasis on both projectile distance and accuracy. Each subject was given several practice trials before data was collected.

Data collected for analysis was obtained in two ways. First, measurements of projectile parameters were made at the site of the performances. After each throw-in, a marker was poked into the ground at the point where the ball was judged to have landed. A tape measure was extended from the marker to form a perpendicular with the target line. The distance from the marker to the target line was the accuracy measure. The distance from the touch line to the intersection of the tape measuring the accuracy was the distance measure (Fig. 1).

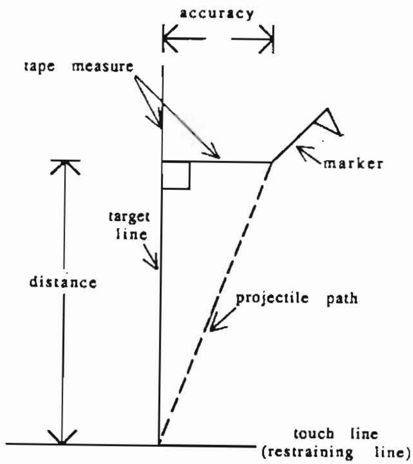

Figure 1. On site measurement of projectile parameters.

Cinematography was the second method used to collect data for analysis. A LOCAM motor-driven 16 mm camera was leveled and aligned with the optic axis of its lens perpendicular to the sagittal plane of movement of the right side of the subjects' performances. The camera's frame rate was set at 100 Hz. Prior to filming the subjects, a meter stick and a vertical reference were filmed in the plane of the activity as a reference for distance and angular measurements, respectively. Timing lights with an effective frequency of 1000 Hz, placed in the field of view, were used to check the camera's frame rate. One performance of the standard throw-in and six performances of the handspring throw-in by Subject 1 and three performances of the standard throw-in by Subject 2 were filmed.

Film data were analyzed in two ways. First, ball release parameters were calculated from time, distance, and angle measurements. These parameters consisted of the horizontal (V_x) and resultant (Vr) velocity, angle of projection (Θ) relative to the right horizontal, height of release above the ground, and horizontal distance to the vertical plane of the touch line (Fig. 2).

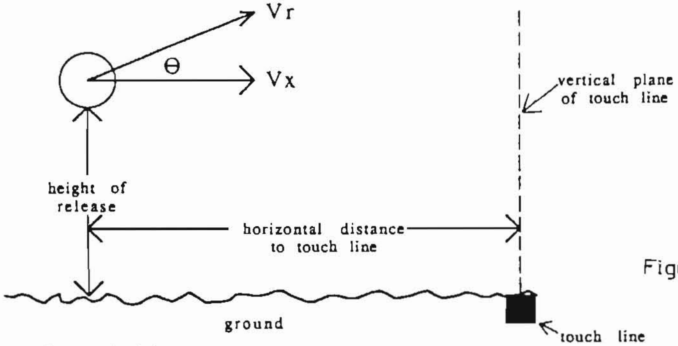

Figure 2. Ball release parameters.

Second, kinematic and kinetic parameters were determined from two dimensional Cartesian coordinates of body landmarks and the ball and from body segment mass data according to Dempster (2). Coordinates were obtained on-line by digitizing film images projected by a Vanguard Motion Analyzer onto a screen surface. Before calculating kinematic and kinetic parameters, coordinate arrays were passed through a fourth order Butterworth filter and then differentiated via first central finite difference techniques. Data were collected from the end of the hop, which occurred in both styles following an approach run, to several frames after ball release (Figs. 3 and 4).

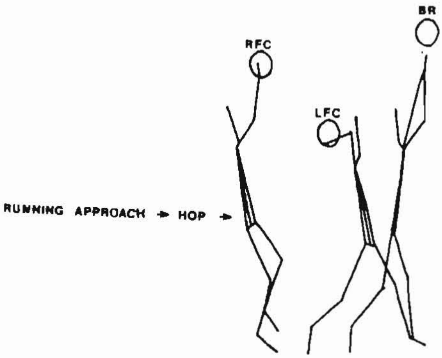

Figure 3. Computer generated stick figure drawing of the standard straddle throw-in which follows an approach run and hop. Note that RFC = right foot contact with the ground, LFC = left foot contact with the ground, BR = ball release and that these labels are positioned relative to ball position.

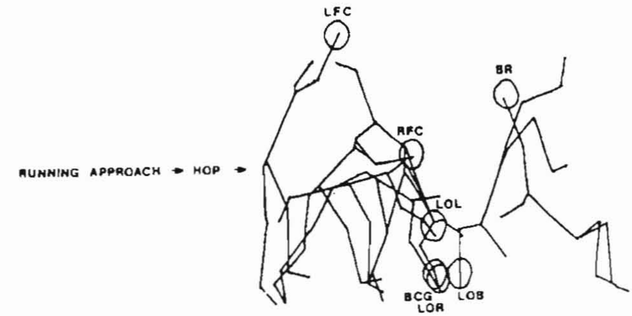

Figure 4. Computer generated stick figure drawing of the handspring throw-in which follows an approach run and hop. Note that LFC = left foot contact with the ground, RFC = right foot contact with the ground, LOL = lift off of the left foot from the ground, BCG = ball contact with the ground, LOR = lift off of right foot from the ground, BR = ball release and that these labels are positioned relative to ball position.

RESULTS AND DISCUSSION

Because a small subject population and few performaces, high level statistical analyses were not possible in this study. Therefore, the results and discussion of this study are limited to a presentation of measured projectile parameters and kinematic analyses of the performances of the standard and handspring throw-ins.

Projectile Parameters Measured On Site

Table 1 contains a summary of the projectile parameters that were measured at the site of the performance. It is evident from Table 1 that the average distance and accuracy in the performance of the handspring throw-in by Subject 1 exceeded the average performance of the standard throw-in by Subject 2 by 8.11 meters and 0.95 meters, respectively. Even though only one standard performance of the throw-in by Subject 1 was filmed, a substantial difference in distance (11.81 meters) existed between this performance and the average distance of the handspring throw-in, without much difference in accuracy.

Parameters Measured From Film

Table 2 contains a summary of ball release parameters. The average angle of projection for the handspring throw-in (23.1 degrees) by Subject 1 is greater than the average angle of projection for the standard throw-in (20.3 degrees) by Subject 2. However, it should be noted that considerable variability existed in both styles. Therefore, from these data, projectile angle does not appear to favor either style in achieving maximum projectile distance. On the other hand, the resultant velocities in all handspring throw-ins exceeded all resultant velocities of the standard throw-ins. Thus, the handspring throw-in for distance had an advantage in the ball velocity vector at release.

The position of release of the ball was also investigated as a variable which influenced projectile distance. From Table 2, it is evident that the height of release was generally consistent in the handspring throw-in by Subject 1 and the standard throw-in by Subject 2 and that the standard throw-in had an advantage in achieving greater projectile distance due to height of release. It should be noted that in all throw-ins the ball was released before the touch line, even though the rules of play permit the ball to be released beyond the touch line. The average performance by Subject 2 had an advantage of 1.20 meters in ball release distance from the touch line when compared to the average handspring throw-in by Subject 1.

The computer analysis and graphical representation of kinematic variables of trial 3 of Subject 2 and trial 2 of Subject 1 were selected for presentation in this paper. These were the best performances in distance of ball projection as measured along the target line. It should be noted that Subject 2 hopped onto his right foot before taking a stride prior to ball release and Subject 1 hopped onto his left foot before taking a stride and executing the handspring maneuver.

TABLE 1
PARAMETERS MEASURED ON SITE

Subject	Trial	Throw-in Technique	Distance[a] (m)	Accuracy[b] (m)
1[c]	1	standard	17.58	-1.35
2[d]	1	standard	22.10	-2.49
2	2	standard	16.10	-1.32
2	3	standard	25.65	-4.04
			$\bar{x}$ = **21.28**	$\bar{x}$ = **-2.62**
1	1	handspring	29.44	-1.63
1	2	handspring	33.02	-0.81
1	3	handspring	20.29	-1.88
1	4	handspring	32.33	-3.33
1	5	handspring	30.33	-1.30
1	6	handspring	30.91	-1.04
			$\bar{x}$ = **29.39**	$\bar{x}$ = **-1.67**

a Distance was measured along a target line (Fig. 1).

b Accuracy was measured as the perpendicular deviation of the point of ball contact with the ground to the target line (Fig. 1).

c For Subject 1, height = 1.80 meters and mass = 64.9 kilograms.

d For Subject 2, height = 1.77 meters and mass = 75.3 kilograms.

TABLE 2
BALL RELEASE PARAMETERS

Subject	Trial	Throw-in Technique	Vx[a] (m/s)	Vr[b] (m/s)	θ[c] (deg)	Height[d] (m)	Distance[e] (m)
1	1	standard	16.06	17.00	19.0	1.83	-0.22
2	1	standard	14.78	16.30	24.5	1.96	-0.60
2	2	standard	17.93	18.16	8.5	1.92	-0.54
2	3	standard	15.60	17.00	28.0	2.06	-0.24
			$\bar{x}$ = **16.10**	$\bar{x}$ = **17.15**	$\bar{x}$ = **20.3**	$\bar{x}$ = **1.98**	$\bar{x}$ = **-0.46**
1	1	handspring	20.60	22.35	21.0	1.37	-2.61
1	2	handspring	17.14	20.95	35.5	1.29	-2.12
1	3	handspring	22.23	22.35	10.0	1.36	-1.36
1	4	handspring	20.60	22.82	24.0	1.39	-1.47
1	5	handspring	19.79	21.65	23.0	1.34	-1.23
1	6	handspring	19.56	21.42	25.0	1.37	-1.59
			$\bar{x}$ = **19.99**	$\bar{x}$ = **21.92**	$\bar{x}$ = **23.1**	$\bar{x}$ = **1.35**	$\bar{x}$ = **-1.73**

a Vx = horizontal velocity at release.

b Vr = resultant velocity at release.

c θ = angle of projection with respect to the right horizontal.

d Height was the distance of the ball above the ground at release (Fig. 2).

e Distance was horizontal distance of the ball to the vertical plane of the touch line (Fig. 2).

Findings on ball velocity, angle of projection, height of release, and projectile distance reported in previous studies (1,5,7) are in general accord with the results of the present study (Table 3). Two results which appear to be inconsistent are the angle of release of 45 degrees reported by Chang (1) and the height of release of 2.32 meters reported by Levendusky et al. (7).

Figures 5 and 6 present a graphical representation of the paths of the center of gravity of the body and ball. In the standard throw-in (Fig. 5), the vertical position of the center of gravity of the body decreases during the stride (Figs. 3 and 5 - RFC through LFC) and then increases as the weight of the body is shifted forward onto the left foot. The center of gravity of the body continues to elevate through ball release (Figs. 3 and 5 - LFC through BR). This striding motion also decreases the height of the ball. However, the decrease in vertical position of the ball is primarily determined by elbow flexion (Fig. 3 - LFC). The motion of both the stride, with forward weight shift, and the flexion and extension in the upper extremity cause a ramp effect on the path of the ball prior to ball release. When comparing Figures 5 and 6 and Figures 3 and 4, it is evident that the standard and handspring throw-ins are very different motor skills. In the handspring throw-in (Fig. 6), the height of the center of gravity initially decreases (Figs. 4 and 6 - LFC through BCG), then increases as the body is inverted, and finally decreases as the feet make

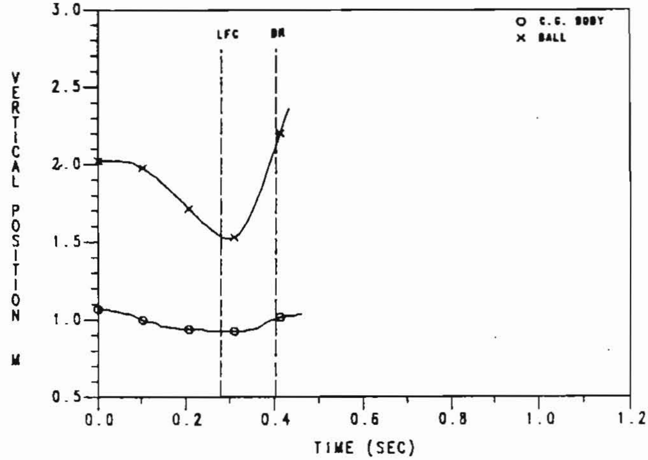

Figure 5. Vertical position for trial 3 of Subject 2 (standard throw-in). Note that RFC, at the end of the hop, occurs at time = 0.0 seconds.

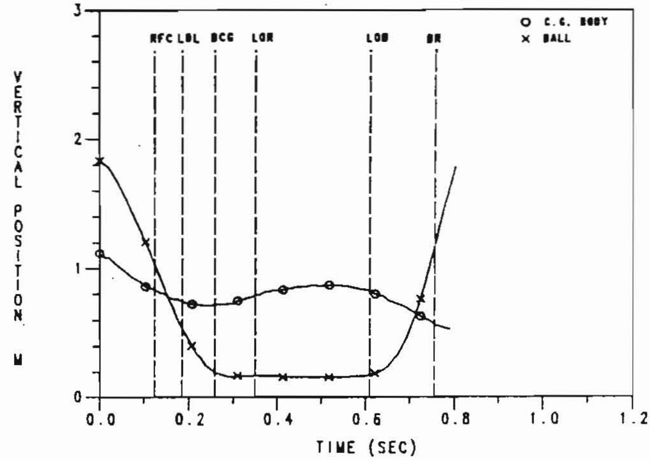

Figure 6. Vertical position for trial 2 of Subject 1 (handspring throw-in). Note that LFC, at the end of the hop, occurs at time = 0.0 seconds and that Subject 2 hops on the opposite foot as Subject 1.

TABLE 3
SUMMARY OF RELATED LITERATURE

Study	Subjects	Throw-in Technique	Ball Release Vr (m/s)	Ball Release Θ (deg)	Ball Release Height (m)	Distance[a] (m)
Chang (1)	experienced soccer player	stride following running approach and hop	15.21	45	1.81	25.30
		handspring	18.25	45	1.45	35.38
Kline (5)	two time All American university player	stride following running approach and hop	21.00	25	2.01	32-41
Levendusky et al. (7)	12 male college varsity players	stride following running approach and hop	18.31	29	2.32	23.14

[a] Projectile range.

contact with the ground and the body assumes a squatting position (Fig. 4 - BR). The path of the ball starts from a relatively high position over the head (Figs. 4 and 6 - LFC), is placed on the ground (Figs. 4 and 6 - BCG to LOB), and then is elevated during the flipping motion. Figures 5 and 6 verify the advantage in height of ball release for the standard throw-in which was previously discussed.

The horizontal velocities of the trunk and ball in the standard and handspring throw-ins are presented in Figures 7 and 8, respectively. In the standard throw-in, left foot contact with the ground blocks the forward motion of the body by either maintaining a rigid and slightly flexed stride leg or by actually extending the stride leg. This action may be somewhat evident in the horizontal linear velocity of the trunk in Figure 7. However, it is this author's experience from executing the throw-in and from observations of players that the forward motion of the trunk is also intentionally inhibited by a forceful eccentric contraction of the extensors of the trunk just prior to ball release. This action creates a whipping effect in the arms to increase ball velocity. The maximum horizontal velocity of the trunk is slightly greater in the handspring throw-in (5.36 m/s) than in the standard throw-in (4.44 m/s). However, they are comparable in value throughout both performances. The horizontal velocity of the ball in the handspring throw-in approaches zero throughout most of the time it is in contact with the ground (Fig. 8 - BCG to LOB). Toward the end of the ground contact phase, the ball begins to slide forward as it is unweighted. The velocity

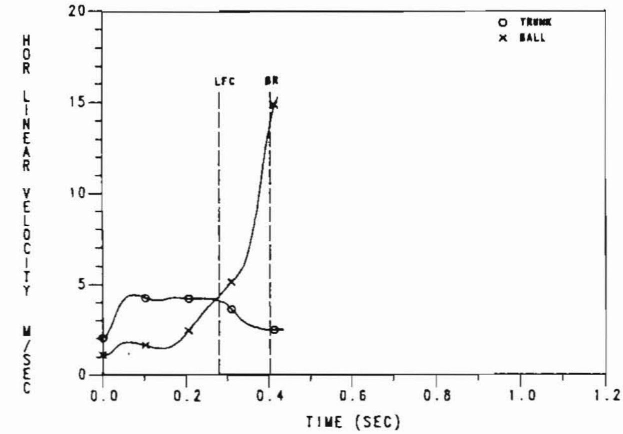

Figure 7. Horizontal linear velocity for trial 3 of Subject 2 (standard throw-in). Note that RFC, at the end of the hop, occurs at time = 0.0 seconds.

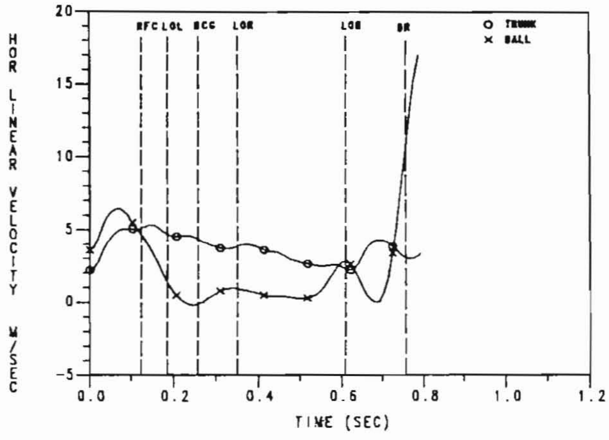

Figure 8. Horizontal linear velocity for trial 2 of Subject 1 (handspring throw-in). Note that LFC, at the end of the hop, occurs at time = 0.0 seconds and that Subject 2 hops on the opposite foot as Subject 1.

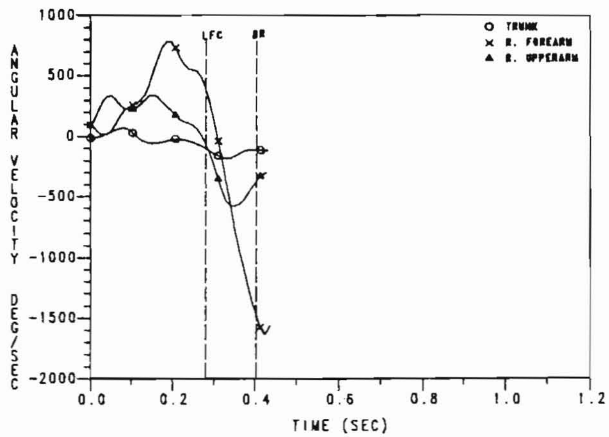

Figure 9. Angular velocity for trial 3 of Subject 2 (standard throw-in). Note that RFC, at the end of the hop, occurs at time = 0.0 seconds. Positive values are counterclockwise.

returns to zero as rearward elbow extension cancels the forward body motion (Fig. 8 - time = 0.60 seconds to time = 0.67 seconds). After this, the horizontal velocity of the ball rapidly increases. This increase in the horizontal velocity of the ball is primarily the result of changes in angular momentum in the trunk, upper arm, and forearm which will be discussed below. It should be noted that the horizontal linear velocity of the ball is shown to continue to increase beyond ball release (BR) in Figures 7 and 8. This anomoly is the result of data smoothing. Table 2 should be consulted for a more exact value of horizontal ball velocity at release.

In both Figures 9 and 10, a classical sequence of increasing angular velocity is evident. Prior to ball release, the angular velocity of the most massive body segment (trunk) reached a maximum followed by a sequencing of less massive body segments attaining greater maximum angular velocities. Table 4 contains a summary of the sequential patterns of the angular velocities of a standard and handspring throw-in. Each of the body segments achieved a greater maximum angular velocity in the handspring throw-in than their corresponding segment in the standard throw-in. The results presented in Table 4 for the standard throw-in are similar to those reported by Levendusky et al. (7).

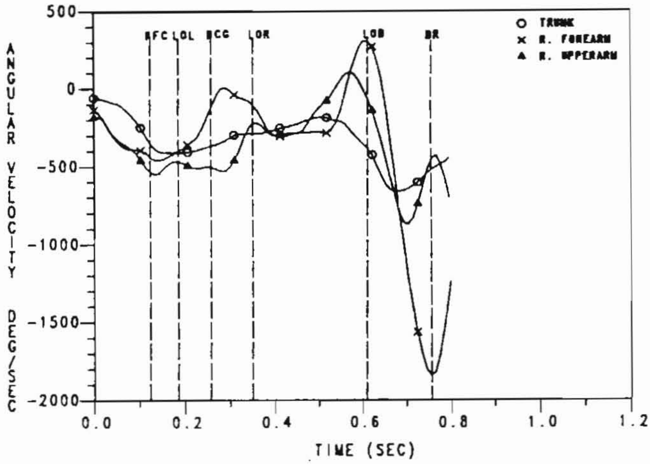

Figure 10. Horizontal linear velocity for trial 2 of Subject 1 (handspring throw-in). Note that LFC, at the end of the hop, occurs at time = 0.0 seconds and that Subject 2 hops on the opposite foot as Subject 1. Positive values are counterclockwise.

TABLE 4
PATTERNS OF MAXIMUM ANGULAR VELOCITY

Throw-In Technique	Body Segment	Trunk	Right Upper Arm	Right Forearm
Standard (trial 3, Subject 2)	Angular velocity (deg/sec)	-184.4[b]	-591.2	-1643.3
	Time (sec)[a]	-0.07	-0.06	+0.01
Handspring (trail 2, Subject 1)	Angular velocity (deg/sec)	-663.9	-877.4	-1847.1
	Time (sec)	-0.10	-0.07	-0.02

a Time was measured from maximum angular velocity to ball release.

b A negative angular velocity value denotes clockwise rotation.

c A negative time value denotes an event before ball release and a positive time value denotes an event after ball release.

TABLE 5
ADVANTAGES AND DISADVANTAGES OF THE STANDARD AND HANDSPRING THROW-IN FOR DISTANCE

Factors		Throw-In Technique: Standard	Handspring
Ball Release Parameters	Resultant velocity	-[a]	+[b]
	Angle of projection	0[c]	0
	Height of release	+	-
	Distance from touch line	+	-
	Distance along target line	-	+
	Accuracy	0	0
	Performance adjustments	+	-
	Skill development	+	-

a A negative sign implies a disadvantage.

b A positive sign implies an advantage.

c A zero implies neither an advantage or disadvantage.

From the present study, the primary factors in achieving maximum angular velocity of the forearm appear to differ in the two throw-in techniques. Blocking of the horizontal velocity of the hip by the stride leg was an important factor in achieving maximum angular velocity of the forearm in the standard throw-in. In the handspring throw-in, ball release followed the return of the feet to the ground, after the handspring, by 0.02 seconds and did not appear to block the forward motion of the hips in order to increase angular velocity of the trunk, upper arm, and forearm. A conservation of angular momentum, generated by the handspring maneuver, appeared to be more important in this technique to achieve maximum angular velocity of the forearm.

SUMMARY

Table 5 contains a listing of factors which have an influence on the results of performance of the standard and handspring throw-in. Only one of the four ball release parameters results in an advantage for the handspring throw-in. Resultant velocity, however, is a dominant factor in achieving maximum projectile distance. A greater resultant velocity was achieved at ball release in the handspring throw-in. This was associated with greater angular velocity at release in the forearm. The standard throw-in appeared to rely more on a blocking of the horizontal velocity of the hip to achieve maximum angular velocity of the forearm. Whereas, in the handspring technique, conservation of angular momentum appeared to be a more important contribution to maximum angular velocity of the forearm.

Two factors, which have not been discussed, are performance adjustments and skill development. Both of these are advantages for the standard throw-in. In the handspring throw-in, performance adjustments cannot be made in the middle of the skill. However, perfomance adjustments to varying game situations are a common practice in the standard throw-in. The handspring throw-in is a complex motor skill requiring many hours of practice to master. Therefore, the soccer coach needs to decide whether or not to divert practice time away from other soccer skills in order to potentially achieve longer throw-ins.

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