EVALUATION OF SPRINT BIOMECHANICS BY MEANS OF AN INSTRUMENTED TRAINING SLEDGE IN SOCCER

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The aim of the study was the functional evaluation of sprint biomechanics by means of an instrumented training sledge in a soccer field. In particular, peak values of the horizontal ground reaction force generated in the first 6 thrusts were estimated after measuring the instantaneous cable tension and the sledge acceleration with a data acquisition system installed on the sledge. Three soccer players were asked to perform 3 couples of 30m sprints (starting once with the left and once with the right leg) while pulling the training sledge: the sledge mass increased in three levels (11.5kg, 16.5kg, 21.5kg). The athletes performed also Bosco tests in monolateral CMJ. Differences in force values between the two legs were more evident after the sledge functional testing in the field than after Bosco monolateral CMJ: the method can suggest functional training procedures to improve the strength of the weak leg and running coordination.

KEY WORDS: soccer, sledge, strength, sprint.

INTRODUCTION: Muscle strength is one of the most important quality in soccer. It is well known that there are several methods to increase all strength components required to a soccer player (Weineck, 1994). One of this is the use of a variable load sledge in short sprints (Cannavacciuolo, 1996). The purpose of the present study was to compare strength values obtained in Bosco monolateral CMJ with force values recorded using an instrumented sledge in the field. In particular, the leg strength was correlated to the peak force values generated by the feet in the first 6 thrusts. A comparison between the two types of exercise was made to evaluate which is more suitable in showing functional differences in strength between the two legs, enabling to define a functional strength training program.

METHOD:

Data Collection: Tests were performed on a regular football field. Three amateur players with long experience in the secondary leagues were involved in the study: data of the testers are summarized in Table 1. Written informed consent was obtained from all the subjects. Tests were performed using a portable data acquisition system SOMAT 2100® FCS installed in a suitable metal sledge with a battery, giving an overall mass of 11.5 kg. A load cell was applied to the cable in order to measure the tension F_t and an accelerometer was placed on the sledge to measure the horizontal acceleration a_x as shown in Figure 1: both sensors were recorded at 200 Hz. The load cell, previously calibrated, was connected to the sledge with a stiff cable of fixed length and to the tester's body with a customized belt.
The duration of each sprint was recorded by three photocells, placed at 0, 10 and 30m from the start line. Each test was filmed with a commercial digital video camera from the right side of the tester. A contact mat system from GLOBUS® was used for monolateral CMJ tests.
After 10 minutes of self-directed warm-up, the three testers were asked to perform Bosco tests (Bosco 1979). Afterwards they performed 3 couples of 30m sprints pulling the sledge, starting once with the left and once with the right leg. The mass of the sledge increased after addition of a 5kg metal disk every set, giving the three load levels of 11.5kg, 16.5kg, 21.5kg.

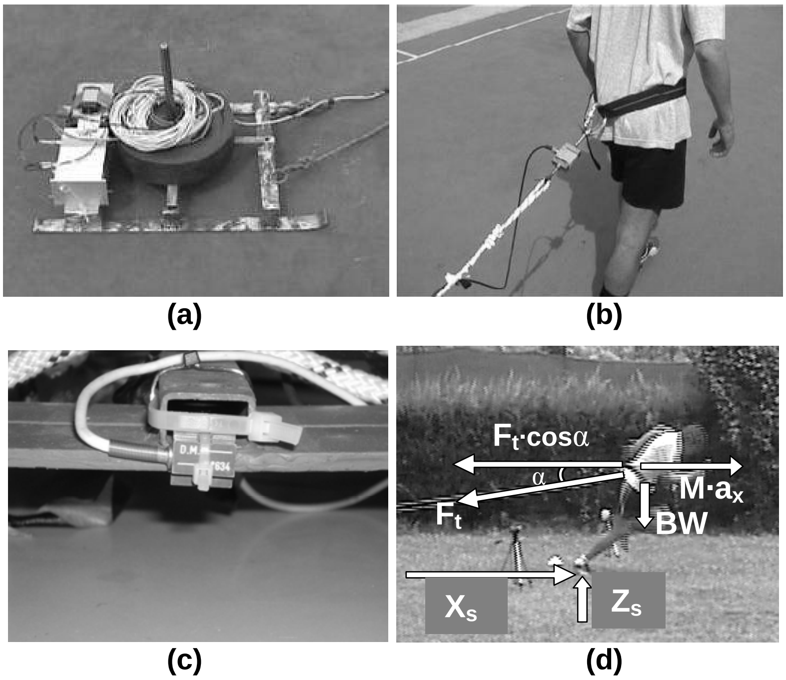

Figure 1: **(a)** Instrumented sledge; **(b)** Load cell placement; **(c)** Accelerometer; **(d)** Free body diagram.

Table 1 Testers involved in the study

TESTER	AGE	HEIGHT [cm]	MASS [Kg]	ROLE
1 (G.M.)	27	184	76	Forward
2 (A.T.)	27	180	71	Midfielder
3 (M.P.)	28	185	78	Midfielder

Data Analysis: For each sprint the sledge acceleration a_x and the traction force to the cable F_t were synchronously measured. All signals were digitally filtered at 5Hz to eliminate the influence of the ground roughness. As a second step, the horizontal ground reaction force X_s developed at the foot sole was instantaneously estimated by the expression (Figure 1d):

$$X_s = M \cdot a_x + F_t \cdot \cos\alpha$$

where M is the total mass of the tester and the sledge. Angles α were established by the cable length and the tester height at pelvis. The analysis was focused on the first part of the sprint and in particular on the first 6 thrusts where highest acceleration is present. In Figure 2 the plot of F_t during the first 6 strides of tester 3 is shown.

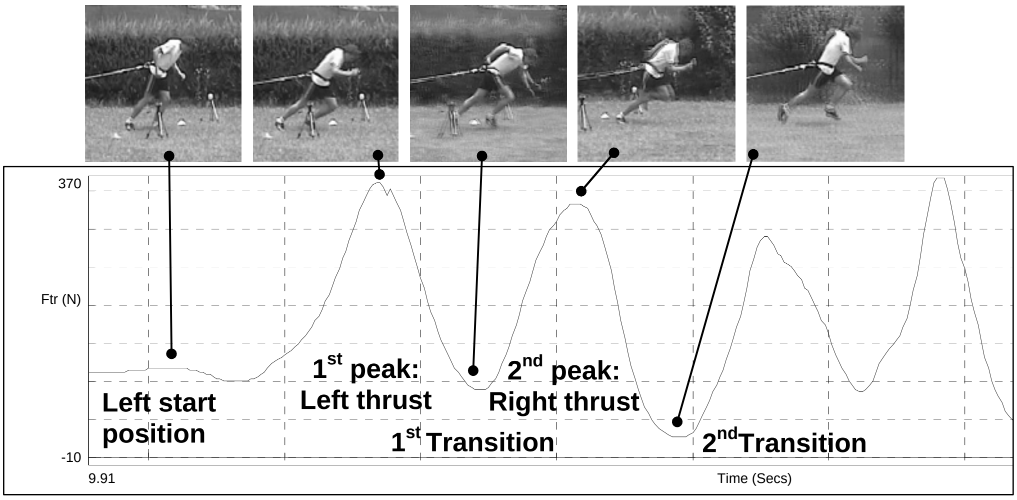

Figure 2: Plot of measured F_t with force peak values for a left start sprint.

RESULTS: The average Bosco test values of the three testers are reported in Figure 3. No appreciable differences in jump height between the two legs were shown except for tester 3 where the left leg seemed stronger than the right one.

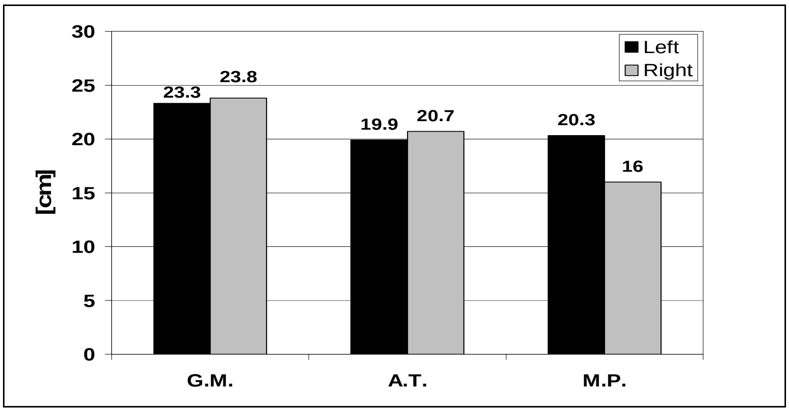

Figure 3: Comparison between right and left jump height in monolateral CMJ test.

The measured traction force F_t and the estimated X_s peak value relative to the first 6 strides of left start sprints with Tester 1 are presented in Figure 4 for the different load levels. The measured signal were processed with peak-valley counting for automatic analysis.

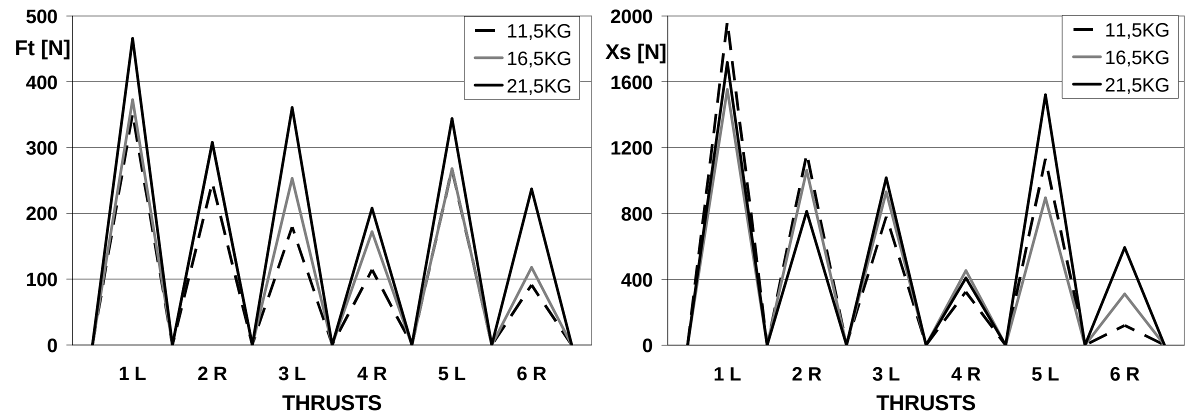

Figure 4: Diagram of F_t and X_s in the first 6 strides of left start sprints at increasing load. (Tester 1)

Peak values of X_s were rearranged within the couple of left/right sprints and normalized to the shortest sprint time in order to perform a comparison between right and left thrusts as presented in Figure 5 where data of Tester 1 and 2 are reported.

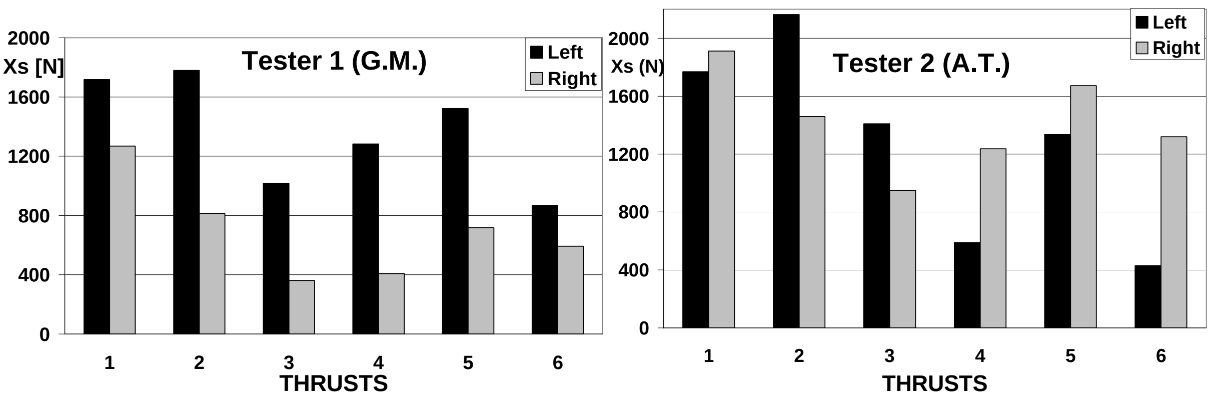

Figure 5: Comparison between the Left and Right Thrusts *Xs* in the first 6 strides at maximum load.

DISCUSSION: The functional evaluation using the training sledge was able to show differences between the two legs and also between testers.

For each player the first thrust was the strongest and this tendency increased at increasing sledge load. The high values of F_t and X_s in the first thrust were due to the use of both legs: for this reason, the second peak was further analysed and compared as reported in Table 2 together with the trial total time at 30mt.

Table 2 Recorded peak value of foot thrust's Xs at 2nd stride

		11.5kg		16.5Kg		21.5Kg	
		Left	**Right**	**Left**	**Right**	**Left**	**Right**
1 G.M.	**Xs/BW**	1.6	1.6	1.9	1.4	2.4	1.1
	Time (sec)	*4.93*	*5.01*	*5.53*	*5.64*	*6.22*	*6.19*
2 A.T.	**Xs/BW**	2.0	1.7	2.2	2.4	3.1	2.1
	Time (sec)	*5.4*	*5.45*	*5.81*	*5.75*	*6.17*	*6.16*
3 M.P.	**Xs/BW**	1.9	2.0	2.3	1.7	2.1	1.4
	Time (sec)	*6.03*	*6.02*	*6.47*	*6.42*	*6.75*	*6.75*

The first 6 thrusts of Tester 1 showed that the left leg was consistently stronger than the right one. Tester 2 presented the left leg stronger than the right mostly in the second and third peak whereas right leg was stronger in the following thrusts. In Tester 3, there was not a clear predominance of one leg: in the first set, where the load of the sledge was 11.5kg, he presented the right leg stronger than the left one but there was an inversion of this tendency at the third level where the load of the sledge was 21.5kg.
Bosco tests results were in contrast with the functional evaluation in the field. In fact monolateral CMJ didn't show appreciable differences between the two legs for Tester 1 and Tester 2 (Figure 3) that were evident from Figure 5. Differences in Tester 3 were not generally confirmed in sprint analysis where the left leg seemed stronger than the right only when the sledge had a higher load.

CONCLUSION: In this pilot study a method to highlight strength differences between the two legs in a functional sprint in the field was developed.

Leg differences were not pointed out with classical monolateral CMJ tests.
The instrumented training sledge can be use as a functional evaluation tool for sprint biomechanics so that a trainer can estimate the leg strength and symmetry and define proper training procedures in order to improve a balanced lower limbs strength that is fundamental for a soccer player.

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