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JUMP LANDING CHARACTERISTICS IN ELITE SOCCER PLAYERS WITH CEREBRAL PALSY

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ABSTRACT: The aim of the present study was to analyse the parameters that characterize the vertical ground reaction force during the landing phase of a jump, and to determine the relationship among these parameters in elite soccer players with cerebral palsy (CP). Thirteen male members of the Spanish national soccer team for people with CP (mean age: 27.1 ± 4.7 years) volunteered for the study. Each participant performed three counter movement jumps. The characteristics of the first peak of the vertical ground reaction force during the landing phase of a jump, which corresponds to the forefoot contact with the ground, were similar to the results obtained in previous studies. However, a higher magnitude of rearfoot contact with the ground (F2) was observed in participants with CP than in participants without CP. Furthermore, a significant correlation between F2 magnitude and the elapsed time until its production (T2) was not observed ($r = -0.474$ for $p = 0.102$). This result implies that a landing technique based on a delay in the production of F2 might not be effective to reduce its magnitude, contrary to what has been observed in participants without CP. The absence of a significant correlation between these two parameters in the present study, and the high magnitude of F2, suggest that elite soccer players with CP should use footwear with proper cushioning characteristics.

KEY WORDS: counter movement jump, injury, vertical ground reaction force

INTRODUCTION

Previous studies have shown that soccer players are exposed to injuries [51], particularly injuries of the lower limb [15,19,24].The injury rate in soccer is estimated to be approximately 10-35 injuries per 1,000 playing hours [13], which is higher than in other sports, such as in handball, basketball, rugby, cricket, badminton, fencing, cycling, judo, boxing, subaqua, and swimming [50-52]. The factors associated with injury production in soccer players have received wide attention [20,23,38,49]. High vertical ground reaction forces (VGRFs) have been identified as the main causes of soccer injury [1,3,21], due to the stress that they place on the musculoskeletal system [39].

During the landing phase of a jump, the impact of the foot with the ground is characterized by two distinct peaks in the VGRF [3]. The first peak (F1) corresponds to the contact of the forefoot with the ground, and the second peak (F2) corresponds to the contact of the rearfoot with the ground [3,28,36,47]. Given that high magnitudes of F2 have been associated with the production of injuries [3, 12,30], a reduction of their magnitude would decrease the injury rate [12,18]. Since the time elapsed from the first contact of the foot with the ground to the production of F2 (T2) is inversely correlated with the magnitude of F2 [41], an increase in T2 would decrease the impact of the rearfoot with the ground. A landing technique based on the synchronized and coordinated flexion of the ankles, knees, and hips during the landing phase has been shown to increase T2 [3,40], thereby reducing the impact of the foot with the ground.

Considering that individuals with cerebral palsy (CP) are very susceptible to injury [16,35,37], soccer players with CP may be a potential target population that could benefit from this landing technique. Persons with CP have a persistent disorder in their locomotion pattern and orthostatic position, mainly caused by a non-progressive brain lesion, injury, or malformation that occurs prenatally or in the first two years of life [6]. Furthermore, CP is characterized by a heterogeneous group of neuromotor conditions involving muscle weakness, morpho-skeletal disorders, and articular instability [8,22,34], which may influence the VGRF characteristics during the landing phase.

Therefore, this study aims to analyse the parameters that characterize the VGRF during the landing phase of a jump in elite soccer players with CP, and to determine the relationships among these parameters.

MATERIALS AND METHODS

Thirteen male members of the Spanish national soccer team for people with CP (mean age ± SD, 27.1 ± 4.7 years; height, 1.74 ± 0.04 m; body mass, 66.4 ± 4.7 kg; body mass index, 22.17 ± 1.85 $kg \cdot m^{-2}$) volunteered for this study. All of the study subjects had participated in at least three international events organized by the International Paralympic Committee or by the Cerebral Palsy International Sport and Recreation Association (CP-ISRA). All subjects had been assigned CP-ISRA and Spanish Sport Federation classifications for people with CP. Both requirements are essential to participate in sport events in the CP category. Prior to involvement in the investigation, all study participants provided written informed consent, as outlined in the Declaration of Helsinki. The study was approved by the Ethics Committee of the Spanish Sports Federation for people with CP.

Procedures

Study participants were required to perform three countermovement jumps (CMJs) interspersed with 45-s recovery periods [26]. All participants refrained from intense exercise 72 h prior to their involvement in the study. Two days before the testing sessions, participants underwent 45 min of technical training to ensure consistent performance during the CMJs. Hands remained at the hips during the entire jump. Minimal flexion of the trunk during take-off was permitted [25], and maximal flexion of the knees during the take-off phase of the CMJ was required to be approximately 90° [2]. On the testing day, participants performed a standardized warm-up consisting of 5-s self-paced low-intensity running, skipping exercises, and two acceleration drills. To avoid any influence of the instructor's feedback on VGRF, no information about landing performance was given to the study participants [31]. The following variables were registered: a) F1 and F2 magnitudes, b) the time from the first contact of the foot with the ground to the production of F1 (T1), c) the time from the second contact of the foot with the ground to the production of F2 (T2), and c) the time to stabilization (TTS).

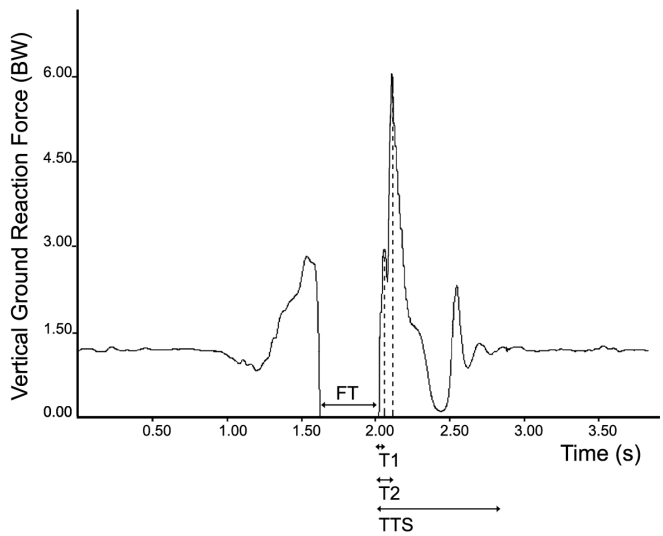

FIG. 1. REPRESENTATIVE GROUND REACTION FORCE (VGRF) CURVE. F1 INDICATES MAGNITUDE OF THE FIRST PEAK; F2, MAGNITUDE OF THE SECOND PEAK; T1, TIME TO PRODUCTION OF F1; T2, TIME TO PRODUCTION OF F2; TTS, TIME TO STABILIZATION

Statistical analysis

Descriptive statistics were calculated for all experimental data. The results are presented as mean ± standard deviation from the mean (SD). All the variables were normal and satisfied the equality of variances according to the Shapiro-Wilk and Levene tests respectively. The VGRF was collected at 500 Hz using a force platform (Kistler, Quattro Jump, Switzerland). The magnitudes of F1 and F2 were identified from the VGRF and normalized by the subjects' body weight [33]. The time from the T1 and T2 were also registered. The TTS was established as the time when the VGRF reached and stayed within 5% of each subject's body weight [5, 29]. Pearson product-moment correlation coefficients (r) were calculated to determine the relationships among the parameters obtained from the VGRF. Statistical significance was set at $p < 0.05$. Data analysis was performed using the Statistical Package for Social Sciences (SPSS Inc, Chicago, IL, U.S.A.).

RESULTS

All study participants utilized a forefoot-rearfoot landing strategy that demonstrated two distinctive peaks (F1 and F2) on the time-history curve of the VGRF. Group mean, standard deviation (SD), maximum (Max), and minimum (Min) VGRF parameters are presented in Table 1. Flight time (FT) is also presented.

Table 2 shows the Pearson correlation coefficients and two-tailed statistical significance levels. The threshold values for Pearson product-moment [44] were used to interpret the results: low ($r \leq 0.3$), moderate ($0.3 < r \leq 0.7$), and high ($r > 0.7$). There were no significant correlations between any variables for $p < 0.05$.

DISCUSSION

The main novelty of this study is to describe and analyse the VGRF during the landing phase of a jump in elite soccer players with CP. High VGRF magnitudes have been related to injury production in

TABLE 1. DESCRIPTIVE STATISTICS OF THE VARIABLES OF THE STUDY

	Mean ± SD	Min	Max
FT (s)	0.455 ± 0.041	0.401	0.534
F1 (BW)	1.921 ± 1.392	0.982	4.259
F2 (BW)	6.462 ± 1.685	2.977	8.692
T1 (s)	0.021 ± 0.112	0.012	0.053
T2 (s)	0.043 ± 0.183	0.016	0.068
TTS (s)	0.461 ± 0.144	0.334	0.902

Legend: SD: standard deviation, Min: minimum value, Max: maximum value, FT: flight time, F1: magnitude of the first peak, F2: magnitude of the second peak, T1: time to production of F1, T2: time to production of F2, TTS: time to stabilization.

TABLE 2. PEARSON CORRELATION COEFFICIENT BETWEEN THE VARIABLES OF THE STUDY

		FT	F1	F2	T1	T2	TTS
FT	Pearson correlation	1	-0.124	0.544	-0.271	-0.442	0.438
	Sig. (2-tailed)		0.687	0.055	0.370	0.130	0.134
F1	Pearson correlation		1	-0.206	0.303	0.464	-0.399
	Sig. (2-tailed)			0.499	0.314	0.110	0.177
F2	Pearson correlation			1	-0.172	-0.474	-0.051
	Sig. (2-tailed)				0.573	0.102	0.869
T1	Pearson correlation				1	0.548	-0.237
	Sig. (2-tailed)					0.053	0.436
T2	Pearson correlation					1	-0.361
	Sig. (2-tailed)						0.225
TTS	Pearson correlation						1
	Sig. (2-tailed)						

Legend: FT: flight time, F1: magnitude of the first peak, F2: magnitude of the second peak, T1: time to production of F1, T2: time to production of F2, TTS: time to stabilization.

different sports [1,3,21], and specifically in soccer [13]. However, until now, no study has assessed the VGRF during the landing phase of a jump in elite soccer players with CP.

The F1 magnitude (Table 1) observed in the present study was similar to previous observations in recreational sports participants without CP (respectively, 1.92 BW vs. 1.51 [10], 1.16 [9], and 1.82 BW [46]). In contrast, F2 magnitude appeared to be higher in the present study than has been previously observed in recreational sports participants without CP (respectively, 6.46 BW vs. 3.67 [10], 2.52 [46], 3.21 [53], 4.29 [48], 3.1 [31], 3.93 [32], and 4.6 BW [30]). Given that landing height has been demonstrated to increase the impact of the foot with the ground [53], we considered that the higher magnitude of F2 observed in our study might be due to higher landing height. However, the landing height in the present study was lower than landing heights documented in previous studies (respectively, 25 cm vs. 30 [30-32,48], 60 [10,46], and 62 cm [53]). The persistent plantar-flexed foot in participants with CP may have created a longer moment arm at the foot in relation to the ankle [17], thereby increasing the magnitude of F2. Furthermore, the muscle activity deficit that occurs shortly before the touch down as a strategy to prepare the muscles to absorb the impact [45] may also have contributed to the higher F2 magnitude observed in participants with CP.

However, in the present study, the time elapsed until F1 and F2 was consistent with the results obtained in similar studies performed with individuals without CP (F1: 21 ms (present study) vs. 16 [47] and 9.15 ms [9]; F2: 43 ms (present study) vs. 36 ms [9]). TTS magnitude (Table 1) was also similar to findings from an earlier study (0.435 ± 0.083 ms) [4]. As TTS is a measure of neuromuscular control obtained by measuring the dynamic stability during the landing phase of a jump [42,43], these results suggest that in spite of the postural instability observed in study subjects with CP [7], postural sway in the vertical direction might not be affected in these individuals. Although a higher TTS was observed in basketball players in a previous study (0.65 ± 0.15 ms) [14], the differences observed in our study may be partly due to arm movement during the landing phase; basketball players had to bring their arms down to a ninety-degree angle and lock them in place upon landing, while in our study participants kept their hands at their hips.

No significant correlations were observed among the VGRF parameters (Table 2). In contrast, the significant correlation previously observed between F2 and T2 in semi-professional soccer players without CP (r = -0.406) [41] and in physically active individuals without CP (r = -0.709) [27] supports the idea of a landing technique based on the synchronized coordination of ankle, knee, and hip flexion in order to delay F2 production, and thereby minimize the impact of the heels with the ground [3]. Nevertheless, the absence of a significant correlation in the present study between F2 and T2 (Table 2) implies that this landing technique might not be effective to reduce the impact of the foot with the ground in elite soccer players with CP. Therefore, we propose that soccer players with CP use footwear with proper cushioning characteristics in order to diminish the impact of the heel with the ground.

No significant correlation has been demonstrated between F1 and F2. These results are in agreement with previous observations in individuals without CP (r = -0.027 [41] and r = 0.233 [27]). These results were expected because F1 is considered a passive component of the landing, and is not influenced by muscular activity [11].

The absence of a significant correlation between TTS and the variables characterizing the contact of the forefoot and rearfoot with the ground (Table 2) suggests that the vertical dynamic postural stability during jump landing might not be affected by the impact of the foot with the ground. Nevertheless, additional research is needed to analyse the dynamic postural stability in the antero-posterior and medio-lateral directions in elite soccer players with CP.

CONCLUSIONS

According to the results of the present study, the characteristics of VGRF that define the impact of the forefoot with the ground are similar between individuals with and without CP. In contrast, elite CP soccer players exhibited higher values of the impact of the rearfoot with the ground. These results suggest a reduced cushioning capacity during the landing phase in elite soccer players with CP.

No significant relationships were observed among the parameters that characterize the VGRF. The absence of a significant correlation between the magnitude of the impact of the rearfoot with the ground and the time elapsed until its production implies that a landing technique based on a delay in the production of this impact might not be effective to reduce the impact of the rearfoot with the ground. This study highlights the utility of footwear with proper cushioning characteristics for elite soccer players with CP.

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