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ORIGINAL INVESTIGATION

Changes in Sprint Force–Velocity Profile in International Para Footballers

Iván Peña-González,[1] Alejandro Javaloyes,[1] Jose Manuel Sarabia,[1,2] and Manuel Moya-Ramón[1,2]
[1]Department of Sport Sciences, Sport Research Center, Miguel Hernández University, Elche, Spain;
[2]Miguel Hernández University of Elche, Alicante Institute for Health and Biomedical Research (ISABIAL), Alicante, Spain

Purpose: Force production is crucial in football, and it is the main limitation of people with cerebral palsy (CP). This study aimed to describe the changes in sprint force–velocity (Fv) profile after a period of 25 weeks of regular training in international football players with CP. ***Methods:*** The sprint Fv profile and other physical performance variables (ie, linear sprint, vertical jump, change of direction, and intermittent endurance) of 14 international players from the Spanish national team were assessed during 2 consecutive training camps. Pretesting and posttesting sessions were carried out 1 week before and after the 25-week intervention period. The intervention consisted of 2 strength sessions per week added to the usual football training. ***Results:*** The repeated-measures analysis of variance showed changes in players' physical performance (linear sprint: $F = 18.05$, $P < .01$; change of direction: $F = 16.71$, $P < .01$; and endurance: $F = 31.45$, $P < .01$) and in some variables of the sprint Fv profile (maximal horizontal force, maximal power, slope, maximal ratio of force, and decrease of ratio of force; $F = 14.28–37.81$; $P < .01$), whereas players' maximal velocity (theoretical and actual) did not change ($F = 0.13$ and 0.01; $P = .72$ and $.98$, respectively). ***Conclusions:*** This study showed that the implementation of 2 strength-training sessions per week, for 25 weeks, is effective to improve CP football players' physical performance. The main finding of this study is the improvement of force application in the acceleration phase (sprint Fv profile), which is the main attribute in many physical performance tests and is the main limitation of the CP population.

Keywords: physical performance, cerebral palsy, disability, para sport

Cerebral palsy (CP) football is a worldwide practiced para sport, which is played by people with CP, acquired brain injury, or stroke (according to the International Federation of Cerebral Palsy Football Classification Rulebook).[1] To be eligible to play CP football, players must have a minimum impairment of hypertonia, athetosis, or ataxia with an impact on their abilities related to game performance.[1] CP football is a 7-a-side modality of football in which time (30-min halves) and field size (70 m × 50 m) are reduced compared with regular football. Nevertheless, the literature has shown that the main physical actions that determine a high performance (eg, accelerations, sprints, or changes of direction among others) are the same as in regular football.[2,3] Both regular and CP football are intermittent sports in which the aforementioned short and high-intensity actions, which are responsible for players' high performance, are alternated with low-intensity recovery periods.[2] Players' physical performance in these determinant actions is usually assessed by linear-sprint, jump, and/or change-of-direction tests,[4–7] whereas the ability to resist the repetition of these high-intensity efforts is usually assessed with intermittent endurance tests (eg, the Yo-Yo Intermittent Recovery Test or the 30–15 Intermittent Fitness Test).[8] An increase in the number of CP football practitioners[5] together with the increasing interest in physical performance assessment in CP football has been reflected in a high number of scientific publications in CP football during the past years. Most of these publications regarding CP football players' physical performance evaluation have been made under the "evidence-based classification criterion/perspective," which has been the basis of the improvement of the players' classification process.[4–6,9,10] However, parallel to this, new research studies regarding the assessment of CP football players' physical performance have tried to show players' conditioning profiles, their adaptations to the training, or even talent identification and selection processes.[7,11–13]

Generally, in football, the assessment of players' physical performance has been related to their neuromuscular performance (shown in their ability to accelerate and sprint, among others) because these short- and high-intensity actions are determinants to succeed in football.[14] Although the traditional assessment of the acceleration (usually 5–10 m) and sprint (20–30 m) has been carried out by recording the time spent in running these distances,[15] a new approach, the sprint force–velocity (Fv) profile, has shown more specific data about players' ability to produce horizontal force (F_0) during the sprint.[16] This assessment is based on the inverse and linear relationship between force and velocity (V_0).[17] The specific features shown by the sprint Fv profile that influence acceleration and sprint performance are related to the player's ability to produce force and power in the horizontal vector and the V_0 they are able to reach and maintain during the sprint. This information allows coaches and conditioning trainers to detect the strengths and weaknesses in sprint performance features of their players and to individualize their training programs according to their players' profiles, aiming to maximize the training adaptations.[15,17] The sprint Fv profile has been used in regular football to detect the physical performance decrement throughout the season[15] or to control the "return-to-play" process after a hamstring injury.[18] It has also been correlated with other physical performance variables from regular football, such as sprinting and jumping abilities.[19] The regular assessment of the sprint Fv profile has been reported as a useful tool to individualize the training process to improve the players' performance and injury prevention.[15]

Javaloyes https://orcid.org/0000-0003-2689-4244
Sarabia https://orcid.org/0000-0002-1917-6634
Moya-Ramón https://orcid.org/0000-0002-2291-5899
Peña-González (ipena@umh.es) is corresponding author, https://orcid.org/0000-0001-6810-0911

As a high physical performance in CP football is related to the production of high amounts of force application in the shortest time possible (ie, to accelerate rapidly), the use of the sprint Fv profile is interesting to assess the mechanical characteristics of sprint in this population in which force production is one of the main limitations (together with coordination).[20] The validity and reliability of the sprint Fv profile to assess CP football players have been recently studied, showing that sprint Fv profile (1) discriminated between CP football players with different impacts of their impairments; (2) correlated significantly with other physical performance variables, such as vertical jump (r = .53–.77), 30-m sprint (r = .83–.99), change of direction (r = .80–.89), dribbling (r = .69–.78), and intermittent endurance (r = .71–.85), indicating that the sprint Fv profile is a valid measure to assess specific physical performance in football; and (3) showed high values of reliability (intraclass correlation coefficients between .77 and .99 across the different variables of the sprint Fv profile and SEMs between 0.89% and 8.88%).[21] The information provided for the sprint Fv profile in CP football could be interesting for coaches and practitioners to determine the degree of the impact of the disability on players' physical performance, and more importantly, it could be a determinant factor to control the players' physical adaptation to the training.

Previous literature has looked into how different training programs have an impact on physical fitness in the CP population.[22–24] However, these studies have some limitations to be applied with para-athletes as the sample included is usually a sedentary population, children, and/or a highly affected CP population (levels 2–5 of the Gross Motor Function Classification Scale),[25] whereas CP football players are characterized by a low activity limitation (level 1 of the Gross Motor Function Classification Scale). In addition, the training programs used by the literature are heterogeneous, focused on therapies, and not adjusted to a low-impaired or highly trained CP population,[26] and they usually report "physical performance" improvements when they are really assessing variables related to "quality of life."[26] More recently, the systematic review of Fleeton et al[27] showed that the CP population is able to reach strength-related adaptations to resistance training programs, but these adaptations cannot be linked to physical performance improvements in sport-specific tests or abilities. They recommended that future research should have a performance focus on the strength training of people with CP, with emphasis on multijoint closed-chain exercises performed at high intensity/velocity and with emphasis on high-demand task assessment.

Fleeton et al[27] concluded that no clear evidence was available regarding functional improvements after a strength training intervention in athletes with CP. They argued that structural and neurological adaptations are possible in the muscles of individuals with CP, but future research should investigate how training interventions could optimize sport-specific adaptations to facilitate meaningful transfer in function and performance in this population. For this reason, the current study aimed to assess the effects of 25 weeks of a combined training program (football-specific training and strength training) on international CP football players' performance, including their sprint Fv profile.

Methods

Subjects

Fourteen international CP football players (age: 27.3 [7.3] y; height: 174.2 [8.0] cm; body mass: 67.5 [9.9] kg; body mass index: 22.1 [1.9] kg·m^{-2}) from the Spanish National Team (ranked 12th out of 84 national teams) participated in the study. Sixteen players were called up to the 2 training camps included in this study, but only the 14 players who actually attended both training camps were included in the study. All players had a license in the Spanish Sports Federation of People with Cerebral Palsy and were free of injury during the testing sessions and the intervention period. Players included in the study had a minimum of 5 years of experience in CP football training and competition, and they had participated in at least one international tournament or championship. However, they reported little to no experience in strength training. Each participant was informed about the study procedures, and they signed an informed consent according to the Declaration of Helsinki (2013). The protocol of this study was approved by the ethical guidelines of the hosting institution (AUT.DCD.IPG.02.22).

Design

A preintervention and postintervention design was performed to examine the physical performance adaptations of the international CP football players. The intervention consisted of 25 weeks of regular training, which included 2 football-specific training sessions plus 2 strength training sessions per week. Pretesting and posttesting sessions were carried out in 2 consecutive Spanish National Team training camps. Players' physical performance assessment consisted of the measurement of the 30-m linear sprint, including the estimation of the specific features of the sprint Fv profile, the countermovement jump (CMJ), the modified agility test (MAT), and the level 1 of the Yo-Yo Intermittent Recovery test (Yo-YoIR1).

Methodology

Both the initial and final testing sessions started with the anthropometrical measurement (body mass, height, and body mass index calculation) of the players. Subsequently, players performed a standardized warm-up consisting of 5 minutes of low-intensity running, 3 minutes of dynamic stretching, and 3 minutes of high-intensity actions, such as accelerations, changes of direction, and jumps. Players performed all physical performance tests on the same day, following the same order and with identical procedures and conditions. Players performed all the tests on a synthetic grass pitch and wearing their football-specific boots, except for the CMJ, which was performed with their usual footwear. They performed 2 attempts of each test, except for the Yo-YoIR1, and the best attempt was registered for further analysis. Players were verbally encouraged to perform each test at their maximal effort.

Anthropometrics

Players' body mass was assessed with a digital body composition monitor (Tanita BC 601 Ltd). Players' height was measured with a fixed stadiometer (SECA Ltd). Body mass index was calculated as body mass (kg)/(height [m^2]).

Countermovement Jump

The players' vertical jump height was assessed by a free-arm CMJ. Players performed the CMJ without placing their hands on their hips as their impairment may have affected their upper limbs. Two attempts of the CMJ with 1-minute rest were performed by the players, and one extra attempt was allowed if one of the attempts was null. The CMJ was recorded using a contact platform (Globus Ergotester) (Figure 1A).

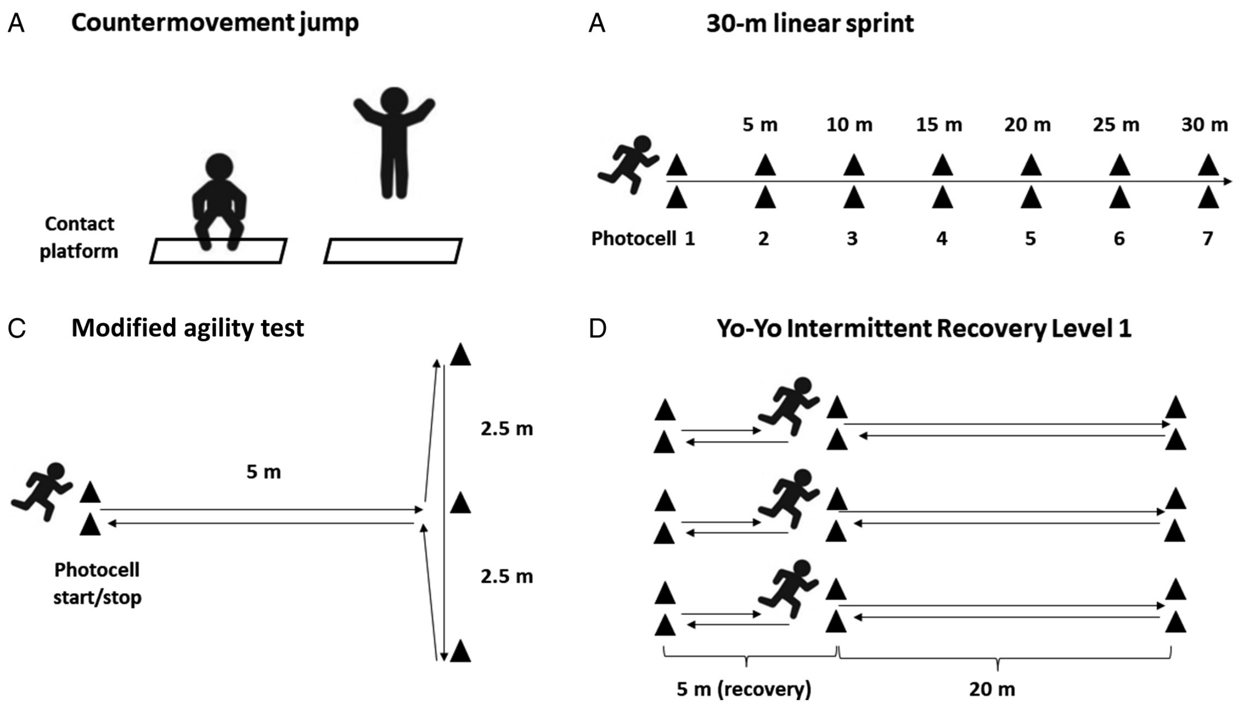

Figure 1 — Graphical description of physical performance tests.

Thirty-Meter Sprint and Sprint Fv Profile

The time in a 30-m linear sprint (Figure 1B) was recorded using photoelectric cells (Witty System, Microgate). Partial times every 5 m were also recorded and used to estimate the player's sprint Fv profile. Players started from 30 cm behind the starting line in a standing position. The specific variables derived from the sprint Fv profile were the theoretical maximal capability to produce F_0 and V_0, the associated maximal power output (P_{max}), the slope of the Fv relationship (Fv_{slope}), the theoretical maximal effectiveness in the force application on the horizontal vector (RF_{max}), the capability to maintain the inevitable decrease in F_0 production when the V_0 increased (D_{RF}) and the estimation of the maximal V_0 (V_{max}).[17] These variables were calculated according to Samozino et al[16] and using their specific spreadsheet.

Modified Agility Test

Time in the MAT[28] was used to assess the players' change of direction ability (Figure 1C). This test was also adapted to perform it with a forward direction during the whole test, avoiding lateral and backward movements, which are less usual in football.[29] The rule of "touching the cone" was also eliminated as the participants' disability may have had an impact on their upper limbs, and without this rule, they were able to focus on the rapid change of direction. This modification of the original test was used in Peña-González et al[7] with 75 national and international CP football players and showed good values for the validity (discrimination between national and international players) and reliability (intraclass correlation coefficient = .92; SEM = 0.36). Players started 30 m behind the start/finish photoelectric cell (Witty System, Microgate) in a standing position.

Yo-Yo Intermittent Recovery Test Level 1

The Yo-YoIR1[30] was used to assess the players' intermittent endurance (which is more specific for football than continuous endurance; Figure 1D). This incremental speed running test consisted of performing 2 × 20-m shuttle runs with a change of direction and with a 10-second recovery after the 40-m shuttle. The test finished when players could not reach 2 consecutive marks at the beep signal (which indicated that they could not maintain the velocity due to fatigue).

Training Program

The participants of the study carried out 2 football-specific training sessions per week. These training sessions were maintained for this study, and the investigators did not have influence in this training content except in the instruction that they could not carry out strength-specific sessions. In addition to these 2 football-specific training sessions, players performed 2 extra strength training sessions per week. The aim of the strength training sessions was to develop the players' force production as it was one of the main limitations (because of their disability) of their physical performance.[20] The specific exercises selected for the strength training intervention were as follows: squat, frontal lunge, side lateral lunge, hip thrust, dead lift, and ankle plantar flexion. The exercises were performed with the players' own weight due to their scarce experience in strength training. The volume of the strength training sessions increased progressively with the objective of increasing the training load throughout the intervention: weeks 1 to 5: 3 bouts of 8 repetitions (24 repetitions per exercise), weeks 6 to 10: 3 bouts of 10 repetitions (30 repetitions per exercise), weeks 11 to 15: 3 bouts of 12 repetitions (36 repetitions per exercise), weeks 16 to 20: 4 bouts of 10 repetitions (40 repetitions per exercise), and weeks 21 to 25: 4 bouts of 12 repetitions (48 repetitions per exercise). Players were asked to perform each repetition with maximal intent.

Statistical Analysis

Descriptive data for the sprint Fv profile (F_0, V_0, P_{max}, Fv_{slope}, RF_{max}, D_{RF}, and V_{max}) and the other physical performance variables are presented as means and SD. The Shapiro–Wilk test confirmed the data normality before the statistical analysis. A repeated-measures analysis of variance was used to assess the changes in the sprint Fv variables and the other physical performance tests between the pretesting and posttesting sessions. Due to the small sample size (n < 20), the standardized differences or effect sizes (ES) at 95% confidence interval between sport classes were expressed in Hedges *g* units, according to the recommendations of Lakens and Bakker,[31] and they were interpreted as trivial (<0.24), small (0.25–0.49), moderate (0.50–0.99), and large (> 1.00).[31–33] The probability that the training intervention was clinically positive, trivial, or negative was calculated using the magnitude-based decisions method described by Hopkins.[34] The smallest worthwhile standardized difference in means (the mean difference divided by the between-subject SD) was set at 0.2, representing the hypothetical smallest change required for the training intervention. This data analysis provided a qualitative descriptor according to the chances of benefit.[34] All calculations were performed using Microsoft Excel and SPSS Statistics® (Statistical Package for the Social Sciences, version 27.0), and the level of significance was set at $P < .05$.

Results

Pretesting and posttesting descriptive data of the sprint Fv profile and the rest of the physical performance tests are shown in Table 1. Graphical change in players' sprint Fv profile between preintervention and postintervention is shown in Figure 2. The analysis revealed changes from 3.6% to 22.9% between the pretesting and posttesting sessions for some of the sprint Fv profile variables (F_0, P_{max}, Fv_{slope}, RF_{max}, and D_{RF}), with *moderate* to *large* ES and with *very* to *most likely* clinical changes ($P < .01$) (Figure 3). However, other variables, such as V_0 and V_{max}, revealed *trivial* effects ($P > .05$). The repeated-measures analysis of variance also showed changes from 3.2% to 46.5% between the pretesting and posttesting sessions for the 30-m sprint, the MAT, and the Yo-Yo IR1, with *small* to *moderate* ES and *likely* to *most likely positive* changes ($P < .01$), whereas the CMJ presented *trivial* ES with *unclear* changes ($P > .05$).

Discussion

To the authors' knowledge, this is the first study that examined the physical performance adaptations to a regular training program in international para footballers with cerebral palsy, which suggests that CP football players are able to improve their football-specific physical performance by combining their usual football training with strength training. In addition, this is the first study that examined the changes in the sprint Fv profile after a training program in CP football. The main finding of the present study revealed that international CP football players had *small* to *moderate* improvements in their physical performance (eg, linear sprint, change of direction, and intermittent endurance performance) after 25 weeks of football-specific training and strength training. The assessment of the sprint Fv profile revealed that players' physical performance enhancement was mainly due to an increase in their F_0 application at low velocities rather than at high velocities.

Both regular and CP football physical performance is determined by a player's ability to perform specific actions (eg, a change of direction) at high speeds (or to do this action in a shorter period of time) and their ability to repeat these high-intensity actions.[14] Previous literature has shown physical performance improvements in sprint, jump, change of direction, and endurance after combined training programs in regular football.[35,36] However, there is no previous literature that has analyzed sport-specific physical performance improvements after a training program in CP football. In the present study, the application of the training program, which included a combination of football-specific training and strength training, showed likely to most likely positive effects ($P < .01$) (see Figure 3) in the 30-m sprint, the MAT, and the Yo-YoIR1. These results suggest that CP athletes are able to show sport-specific physical performance adaptations to the training, which may answer the question derived from Fleeton et al,[27] who reported the necessity of research about how the performance capacity of

Table 1 Descriptive Data (Mean [SD]), Percentage of Change, Magnitude of Change, and Significance for the Differences Between Preintervention and Postintervention Testing Sessions

	Pre	Post	% change	*F* (*P*)	Hedges *g* (95% CI)
Sprint Fv profile					
F_0, N·kg^{-1}	10.53 (2.57)	12.90 (2.22)	22.6	24.18 (<.001)	0.96 (0.18 to 1.74)
V_0, m·s^{-1}	7.08 (0.87)	7.03 (0.71)	−0.6	0.13 (.722)	−0.06 (−0.80 to 0.68)
P_{max}, W·kg^{-1}	18.81 (5.54)	22.91 (5.46)	21.8	37.81 (<.001)	0.72 (−0.04 to 1.49)
Fv_{slope}, N·s·m^{-1}·kg^{-1}	−1.49 (0.34)	−1.83 (0.24)	22.9	15.33 (.002)	−1.12 (−1.92 to −0.32)
RF_{max}, %	44.0 (4.0)	46.0 (4.0)	3.6	15.39 (.002)	0.49 (−0.27 to 1.24)
D_{RF}, %	−14.0 (3.0)	−17.0 (2.0)	22.5	14.28 (.002)	−1.14 (−1.94 to −0.34)
V_{max}, m·s^{-1}	6.89 (0.81)	6.89 (0.68)	0.0	0.01 (.987)	0.00 (−0.74 to 0.74)
Physical performance tests					
30-m sprint time, s	5.08 (0.57)	4.92 (0.49)	−3.2	18.05 (.001)	−0.29 (−1.40 to 4.45)
CMJ, cm	33.15 (7.21)	32.99 (6.49)	−0.5	0.03 (.877)	−0.02 (−0.76 to 0.72)
MAT, s	6.74 (0.84)	6.46 (0.70)	−4.2	16.71 (.001)	−0.35 (−1.10 to 0.39)
Yo-YoIR1, m	645.7 (267.1)	945.1 (424.7)	46.5	31.45 (<.001)	0.82 (0.05 to 1.59)

Abbreviations: CMJ, countermovement jump; D_{RF}, decrease in the ratio of horizontal force; ES, effect size; F_0, theoretical maximal force production; Fv, force–velocity; Fv_{slope}, force–velocity slope; MAT, Modified Agility Test; P_{max}, theoretical maximal mechanical power in the horizontal direction; RF_{max}, maximal value of ratio of horizontal force; V_0, theoretical maximal running velocity; V_{max}, maximal velocity; Yo-YoIR1, Yo-Yo Intermittent Recovery Level 1.
*$P < .01$.

athletes with CP may be influenced through training. The tests used to assess the physical performance of football players have been validated with able-bodied individuals rather than athletes with CP. However, the physical performance tests used in the present study have been previously used to describe this population. The linear sprint, MAT, and dribbling tests have been used in several studies with CP football players with different purposes as the evidence-based classification process[6] or talent identification and selection processes.[7] The CMJ has also been used with international CP football players,[7] and it presented good validity as there were significant differences in the CMJ between players with different sport class.[37] De Freitas et al[8] reported Yo-Yo IR1 values for international CP football players, and they showed lower performance of this sample in this test than able-bodied football players. Nevertheless, all these tests have been used in this population to describe it, but this is the first study that shows changes in these tests after a regular training intervention.

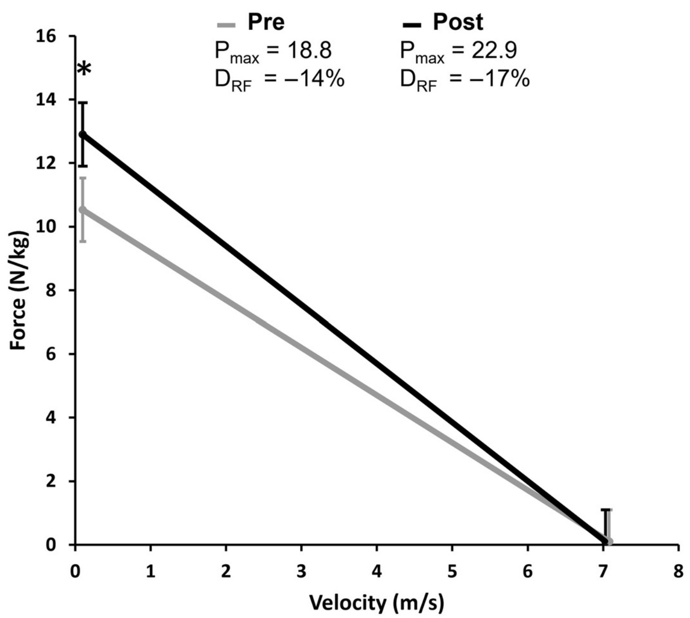

Figure 2 — Sprint (force–velocity) profiles for pretesting and posttesting sessions. DRF indicates decrease in the ratio of horizontal force; Pmax, theoretical maximal mechanical power in the horizontal direction. *$P < .01$.

Surprisingly, the vertical jump (CMJ) did not improve in this study after the described training program. There are some possible reasons that could help to explain this result. First, players were allowed to perform the CMJ without a strict movement pattern (eg, range of motion in the eccentric–concentric phase or allowing arm swing) due to their impairment limitations. In addition to this, the CMJ test requires high intermuscular coordination,[38] which is a limitation of the CP population, especially in ataxic CP.[20] Finally, unilateral spastic profiles may have also influenced the technique in this test due to a significant asymmetry in the jump. All these possible interindividual differences in the movement patterns due to the different impairment profiles or coordination abilities could increase the error associated with this test in this population, which could have been the main reason why the changes in the CMJ were not detected after the training program. This contrasts with the previous literature that has evaluated the CMJ in the CP population.[37,39] However, this previous literature forced the participants to keep their hands on their waist and, at the investigator's command, perform the eccentric phase until their knees reached 90°.[39] The authors acknowledge that this is the gold-standard procedure for the CMJ test, but the variability in the participants' profiles in this study (which are the same profiles that are usually found in the practical field of CP football) made following this procedure impossible. For example, people with upper-limb spasticity are not able to put or maintain their hands on their hips, or people with high spasticity in the lower limbs are not able to flex their knees at 90° with ease. In addition, ataxic and athetotic profiles have several coordination limitations to follow the movement pattern of a strict CMJ between series (reaching their braking phase at 90° of knee flexion).

There is consistent evidence in previous literature that indicates that resistance training enhances muscular strength in the CP

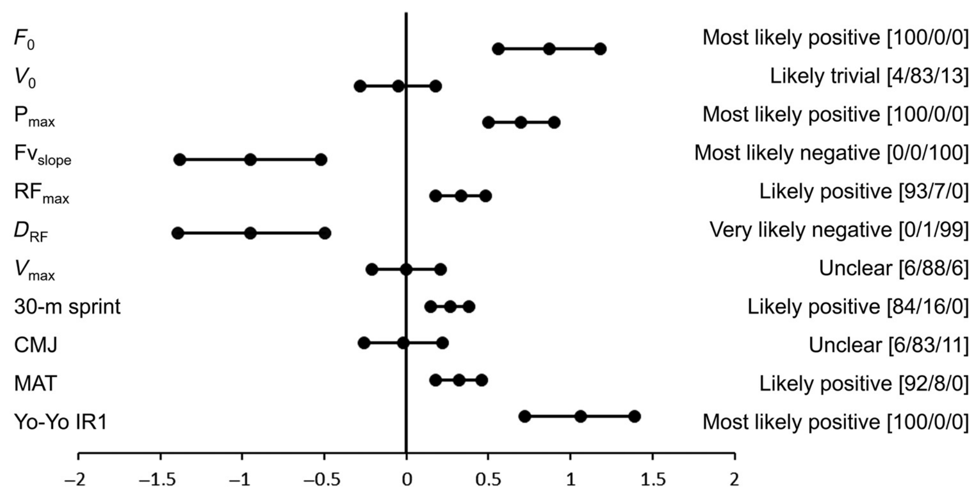

Figure 3 — Clinical/practical interpretation of the effect of the training-program intervention in the analyzed physical performance variables. CMJ indicates countermovement jump; D_{RF}, decrease in the ratio of horizontal force; F0, theoretical maximal force production; Fv_{slope}, force–velocity slope; MAT, Modified Agility Test; P_{max}, theoretical maximal mechanical power in the horizontal direction; RF_{max}, maximal value of ratio of horizontal force; V_0, theoretical maximal running velocity; V_{max}, maximal velocity; Yo-Yo IR1, Yo-Yo Intermittent Recovery Level 1.

population, but it is not clear whether individuals with CP can improve their function (eg, walking) or physical fitness/performance (eg, sprint time) as a result of that strength training.[27] In addition to this, most of the research on this topic (1) includes children, sedentary, or highly impaired people with CP; (2) is focused on quality of life; and (3) uses training methodologies that are not generalizable to a low-impaired (level 1 of the Gross Motor Function Classification Scale) and moderate-trained CP population.[26,27] As reported by Fleeton et al,[27] the anthropometric and physical and physiological characteristics of CP athletes from several para sports have been reported, but there is no evidence of how physical performance is influenced by training in CP athletes. In this regard, the present study suggests that CP football players are able to improve their sprint-related performance after strength training (in combination with their usual football training), which is in line with the ample previous literature with able-bodied athletes and football players.[40–42] Improvements in the force production (eg, in the back squat exercise) have been related to improvements in short-sprint performance (<30-m sprint),[41,42] and several strength training interventions and methodologies have been related to improvements in sprint performance.[40,41] This relationship between force production and sprint performance has been previously explained by a higher peak reaction force, impulse, and rate of force development during the running of those people with greater lower-body strength.[41] Moreover, a general strength improvement after a training program has an impact on F_0 production, which could be especially notable in the CP population due to their limitation in force production because of their disability. Although further research is necessary, to date, there is no reason to consider that the CP population (especially CP athletes with low impairment) are not able to have similar physical performance adaptations (eg, sprint performance) after a strength training program as able-bodied athletes.

Together with the players' physical performance enhancement, some of their sprint mechanical characteristics improved after the training program (F_0, P_{max}, Fv_{slope}, RF_{max}, and D_{RF}). However, other variables from the sprint Fv profile did not change: (V_0) and (V_{max}). According to the interpretation of Samozino et al[16] about the variables of the sprint Fv profile, the results of this study suggest that CP football players improved their physical performance in the 30-m sprint, the MAT, and the Yo-YoIR1 due to their improvements in force production in the horizontal vector (represented by the increase in F_0) and their P_{max} in the horizontal direction (increase in P_{max}) but without improving their V_{max} (nonincrease in V_0 and V_{max}). Consequently, their effectiveness in the RF_{max} improved, Fv_{slope} increased, and D_{RF} decreased. This finding is in accordance with the hypothesis that it is possible to improve maximal running capability by focusing on different points of the sprint Fv profile.[17] This revealed that strength training has an impact on the first part of the Fv relationship (see Figure 3), improving force application mainly in the first steps of the sprint (acceleration phase). This is important for coaches and conditioning trainers as during a match, CP football players perform an average of 1.06 moderate (1.0–2.78 $m \cdot s^{-1}$) and 0.07 high (> 2.7 $m \cdot s^{-1}$) accelerations and between 0.9 and 0.13 high-intensity changes of direction per minute.[43]

The players' improvements of their F_0 and P_{max} are also related to their improvement not only in the 30-m sprint time (by reducing the time in the first meters or in the acceleration phase) but also in the change of direction ability (MAT; as the ability to accelerate is crucial to carry out a better change of direction) and in the intermittent endurance (Yo-YoIR1) test (because this test includes repeated accelerations and changes of direction in its protocol). Thus, caution is necessary when interpreting the results regarding the improvement in the Yo-YoIR1. The results of this study cannot demonstrate an improvement in the "aerobic parameters" of the athletes, but they could be improving in this test by means of an improvement in their efficiency in acceleration and change of direction. Given the relevance of force production in acceleration and sprint performance and considering muscle weakness as one of the main impairments of people with CP, the combination of football-specific training and strength-based training may be a good option to improve CP football players' physical performance in sprint and change of direction.

However, some limitations should be reported in this study. The sample has a heterogeneous CP diagnosis, but the sample size in this study did not allow the analysis of physical performance changes after the training program according to the players' sport class (which indicates the severity of the player's impairment and the impact on the game) or according to the players' impairment profile (eg, spastic diplegia, hemiplegia, athetosis, or ataxia). Another limitation of this study is that a control group (without strength training) was not included in the study to compare the results obtained between groups. This is a major limitation of the study, and the conclusions should be taken with caution. Future research should compare the effects of a training program between CP football players who include strength training and CP players who do not include strength stimulus. In addition, it could be interesting to research CP football players' training adaptations compared with a control group of players without CP. However, although the sample size was small and the study did not have a control group, the members of the sample included in this study were the international CP football players of a country, which implies that it is a representative sample. In addition, this study has been developed in an ecological environment in which the application of different training stimulus to the same group (team) was not feasible. Most players stated that they were familiarized with strength training, but they reported low strength training volume (ie, once a week and 1 or 2 exercises), low intensities (ie, their own weight), and low experience (1 or 2 y of experience in strength training). An initial strength training session could have been useful to show the initial level of players in strength-related exercises and to familiarize them with the training program. Due to this low experience in strength training, the intensity of the strength training was the same during the whole program, and the volume of the strength training sessions increased progressively with the objective of increasing the training load throughout the intervention. Finally, the football-specific training was not controlled as the technical staff of the national team had the freedom to plan the field sessions as they had to prepare for the World Cup. This limitation did not seem important as all players performed the same group session, although they could have had minimal differences in training loads, depending on their field position.

Practical Applications

1. The implementation of 2 strength training sessions per week, in combination with the players' usual football-specific training, could be a good strategy for CP football coaches and conditioning trainers to develop their players' sprint acceleration.
2. Strength training causes sport-specific physical performance adaptations in the CP population, which was questioned in previous literature, and it is especially interesting in members

of this population, who have a force production limitation due to their disability.

3. The CP football players' physical performance assessment by the sprint Fv profile measurement could be a good strategy for coaches and conditioning trainers in CP football as they can discover their players' strengths and weaknesses in sprint performance, individualize their training stimulus, and observe the specific adaptations produced by their training program.
4. Coaches should adapt their strength training loads to the level and experience of their athletes in this kind of training.

Conclusions

The results of this study showed that a combination of 2 football-specific training sessions and 2 strength-training sessions per week, for 25 weeks, improved the specific physical performance of international CP football players. They improved their results in a 30-m linear sprint test, in a change-of-direction ability test, and in an intermittent endurance test but not in their vertical jump height. The analysis of the sprint Fv profile features showed that the training intervention improved the players' maximal F_0 production in the sprint, their maximal power, their ratio of force applied in the horizontal axis, and their Fv_{slope} profile (reducing the ability to maintain the ratio of force when the speed increases). However, players did not improve their V_{max} (both theoretical and actual), suggesting that their physical performance enhancement was produced by their improvement in force application in the first part of the sprint (acceleration phase), which has an impact on football-specific actions in the game. These findings show that the CP population is able to show sport-specific physical performance adaptations to training that have not been reported yet and that are crucial in people with force-production limitation due to their disability.

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