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Comparison of the vertical jump performance of footballers with cerebral palsy at different competitive levels

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Abstract: Vertical jump (VJ) capacity is a common assessment for monitoring athletes' neuromuscular function and has been proposed as a differentiating indicator between competitive levels of football players. This study aimed to compare the VJ capacity of Chilean footballers with cerebral palsy (CP) with international and national levels of proficiency, also according to their sport classes (i.e., FT1–FT3). A total sample of 41 male footballers with CP were divided into international-level (n = 18) and national-level (n = 23) groups. All the participants performed two maximal squat jumps (SJs) and countermovement jumps (CMJs), where the best height obtained was registered. The VJ performance was significantly different between competitive levels, and players at international level had better scores (p < .001) than the national level in SJ (d_g = 1.83, large) and CMJ (d_g = 2.08, large). Considering the sport classes, significant differences were found in SJ (p = .024) and CMJ (p = .035), in which FT3 players performed higher jumping heights than FT1 players (d_g = -.84 to -1.01, large). These results provide a deeper understanding of the differences in the motor impairment-specific performance of para-footballers with CP, where coaches and strength-conditioning professionals should consider VJ assessment for monitoring training and as a component for talent detection in this para-sport.

Keywords: para-sport; brain impairments; motor impairment; para-football

Introduction

Football is described as a complex discipline involving physical fitness factors that are considered relevant for the realisation of intermittent activities during technical and tactical requirements of the game (Stølen et al., 2005). In this regard, vertical jump (VJ) capacity has a relevant role as a frequent assessment parameter due to the relationship with lower-limb power-generating function and its implication during motor actions performed in vertical and horizontal planes of movement (Dobbs et al., 2015; Mujika et al., 2009; Rampinini et al., 2007). Moreover, VJ is also considered critically important for monitoring training effects (Pagaduan et al., 2019), a suitable method to measure the neuromuscular status (i.e., stretch-shortening cycle; Maulder & Cronin, 2005), and has been supported by certain studies as a differentiating indicator between football players' competitive levels (Arnason et al., 2004; Ruiz-Ariza et al., 2015).

Cerebral palsy (CP) football is a variant of the regular discipline practised by players with neurological conditions related to motor impairments of spasticity, athetosis/dystonia, or ataxia (IFCPF, 2018). This para-sport presents some modifications in technical rules (e.g.,

the no-offside rule), game field dimensions (i.e., 70 x 50 m, goals of 3 x 2 m), and a structured classification system that provides competitive opportunities for para-footballers with CP (Reina, 2014). Currently, the CP football classification allows the categorisation of different functional profiles, allocating para-footballers to three-sport classes (FT1, FT2, and FT3) according to the impact of the eligible impairment on the activity limitation of specific physical and football skills performance (Peña-González et al., 2020; Reina et al., 2020a). Moreover, these three sport classes have a range according to the level of impairment severity, where 1 = severe involvement, 2 = moderate involvement, and 3 = mild involvement are organized by the functional profile of the players. Functional profiles include A = bilateral spasticity, B = athetosis/dystonia or ataxia, and C = unilateral spasticity (Henríquez et al., 2021).

According to previous studies, para-footballers with CP present differentiated responses in terms of the specific demands of the sport, mainly influenced by the impact of the impairment and its severity on physical conditioning parameters (Reina et al., 2020a; Yanci et al., 2018). In this regard, there have been several studies that described a lower anaerobic capacity (Yanci et al., 2016), the existence of lower-limb asymmetries (Alarcón et al., 2021; Reina et al., 2019; Reina et al., 2020b), impaired muscle coactivation (Hussain et al., 2014), and lower force production (Moreau et al., 2012), which could contribute to a reduced VJ output in comparison to non-impaired football players. Clutterbuck and colleagues (2021) suggested that the use of sport-specific gross motor assessments such as running and VJ field testing are suitable procedures to assess higher-level sport ability in children with CP. In that sense, VJ assessment could potentially become a parameter that provides valuable information for talent identification programs, which in the case of para-athletes is mainly influenced by the impairment nature and the classification factor (Dehghansai et al., 2021). Studies performed in football players with CP have shown the utility of the VJ assessment using squat jumps (SJs) and countermovement jumps (CMJs) in the estimation of anaerobic fitness (Yanci et al., 2016) and the distinction between sport classes and with controls (Reina et al., 2018). Additionally, some authors examined kinetic and kinematic characteristics of the VJ performance, such as jump height displacement (Yanci et al., 2014), vertical ground reaction forces (Cámara et al., 2013), peak power output (Yanci et al., 2016) and postural control (Reina et al., 2019) variables, describing the activity limitation of individuals with CP when jumping.

However, the above-mentioned studies were only conducted with high-level international para-footballers, so there is limited information about the differences in performance when comparing players with different levels of sport proficiency. Additionally, the comparison of VJ performance between players at different competitive levels remains unknown, and there is a knowledge gap regarding the potential usage of VJ for talent identification or discrimination between competitive level constructs (Castagna & Castellini, 2013). Therefore, this study aimed to compare the VJ performance of footballers with CP at different competition-levels (i.e., international-level vs national-local) and to describe the VJ proficiency of both levels of footballers with CP according to their sport classes.

Materials and Methods

Participants

A convenience sample of male para-footballers from different national CP football tournaments was recruited to participate in the study. The inclusion criteria were to be classified as Gross Motor Function Classification System Level I (Palisano et al., 2008), belonged to Chilean CP football teams and present a sport class according to the International Federation of Cerebral Palsy Football (IFCPF) classification guidelines. The players were divided into two groups based on their competitive experience level, that is,

international level and national level. The international-level group consisted of para-footballers who had competed in international matches representing a national team (i.e., Americas region and world-level tournaments), whereas the national-level group comprised only players without any international competitive experience. All the players had at least one year of experience at their specific competitive level at the time of measurements. Players' club teams usually performed 1–4 sessions per week and played in local competitive fixtures distributed in four tournaments during the year. Before participation in this investigation, each participant was advised about the experimental procedures involved and signed a written informed consent form. The protocol and experimental procedures approval was obtained from the human ethics committee of Santo Tomas University (Code n° 63.20) following the Helsinki declaration guidelines.

All the para-footballers participated during the 2019–2020 competitive season of the national Chilean CP football tournament, where players performed VJ assessment procedures before competitive matches. The participants were adequately familiarised with testing procedures, and the measurements were performed after a standardised 15 min warm-up, including light jogging, changes of direction, skipping exercises, two acceleration drills, and self-administered submaximal attempts of SJ and CMJ practice (Mujika et al., 2009). To determine the VJ height performance as done in previous studies in footballers with CP (Reina et al., 2018; Yanci et al., 2014), the players performed two maximal SJs and CMJs using a jump platform (2.5, DMJUMP, Santiago, Chile) placed on a stable surface.

Vertical jump assessments

For the realisation of the SJs, the players were instructed to jump as high as possible from an initial static position with an approximate 90° knee flexion angle maintained for 2 seconds before the attempts, without any rebound or countermovement during the jump (Loturco et al., 2015). In the CMJs, the participants start from an erect position performing a rapid flexion-extension downward movement until the knees reach an angle of 90°. Then, they immediately jumped vertically for maximum height (Markovic et al., 2004). For all the attempts, verbal instructions and encouragement was provided for better performance (Coswig et al., 2019). Each player performed two maximal SJs and CMJs with 1 min rest between trials and 5 min of recovery between each jumping test. For statistical analysis, the best height, in centimetres, obtained was registered. For both jumps, hands remained at the hips during the entire movement; however, those athletes who presented spastic hemiplegia and difficulty maintaining their hands to their hips were allowed to keep their hands on the side of their body (Yanci et al., 2016). Additionally, the elastic index (EI) was obtained to analyze the effect of the stretch-shortening cycle calculated by the following formula used in previous studies:

$$EI = [(CMJ - SJ) \cdot 100] / SJ$$

where the EI is expressed in % (Bosco & Komi, 1979; Yanci et al., 2014; Yanci et al., 2016).

Statistical analyses

The results are presented as means (*M*) and standard deviation (*SD*). Assumptions of normal distribution and homogeneity of variance were verified using Kolmogorov–Smirnov and Levene's test, respectively. A 2x3 design multifactorial analysis of variance (ANOVA) was used to compare VJ height performance and the EI considering the competitive level (international vs national) and sport classes (FT1, FT2, and FT3), also explored the interaction between both between-group factors. Tukey's post hoc test was performed to determine pairwise comparisons between the levels of the players' sport classes. Partial eta-

square ($\eta\rho^2$) values were obtained from the ANOVA analyses as a measure of effect size for mean differences with the following interpretation, above .26, between .26 and .02, and lower than .02 were considered as large, medium, and small, respectively (Pierce et al., 2004). To calculate the effect size for pair comparisons, Hedges' *g* index was used (Hedges & Olkin, 1985). This index is based on Cohen's *d* index (Cohen, 1988), but it provides an effect size estimation reducing the bias caused by small samples (n < 20). Interpretation of Hedges' *g* above .80, between .50 and .79, between .25 and .49, and lower than .25 and were considered large, moderate, small, and trivial, respectively. The statistical analyses were performed using the SPSS version 26 and the statistical package GraphPad Prism (version 8.2; GraphPad Software, San Diego, CA, USA). The significance level was set at $p < .05$.

Results

A sample of forty-one male para-footballers (age: *M* = 24.7, *SD* = 8.0 yrs; height: *M* = 169.8, *SD* = .1 cm; body mass: *M* = 69.5, *SD* = 11.4 kg; body mass index [BMI]: *M* = 24.1, *SD* = 3.7 kg·m^{-2}) took part in the study. The participants were divided in groups according to their level of proficiency: i.e., international-level (n = 18; age: *M* = 26.4, *SD* = 6.4 yrs; height: *M* = 171.1, *SD* = .1 cm; body mass: *M* = 70.7, *SD* = 10.4 kg; BMI: *M* = 24.2, *SD* = 3.4 kg·m^{-2}) and national-level (n = 23; age: *M* = 23.5, *SD* = 9.0 yrs; height: *M* = 168.8, *SD* = .1 cm; body mass: *M* = 68.5, *SD* = 12.3 kg; BMI: *M* = 24.0, *SD* = 3.9 kg·m^{-2}) groups (Table 1).

Table 1. Football players' with cerebral palsy characterisation according to sport classes and competitive level.

Competitive level	**International (n = 18)**			**National (n = 23)**		
Sport Class	FT1	FT2	FT3	FT1	FT2	FT3
Bilateral spasticity	1	0	0	2	1	0
Ataxia / Athetosis	1	0	1	2	0	0
Unilateral spasticity	1	12	2	1	12	5
Overall sample	3	12	3	5	13	5

FT: Cerebral palsy football sport classes.

Considering players' competitive level, the international-level para-footballers of this study had a statistically significant better jumping performance compared to national-level ones ($p < .001$; $\eta\rho^2$, SJ = .41, large and CMJ = .51, large), both for the SJ [Figure 1A: (International: *M* = 27.8, *SD* = 5.3 cm vs National: *M* = 19.0, *SD* = 4.4 cm; d_g = 1.83, large)] and CMJ [Figure 1B: (International: *M* = 30.5, *SD* = 5.0 cm vs National: *M* = 21.0, *SD* = 4.2 cm; d_g = 2.08, large)] jumping tests. However, for EI, no statistically significant differences ($p = .645$) were found between the international and national levels athletes (International: *M* = 10.6, *SD* = 7.6% vs National: *M* = 12.4, *SD* = 15.5%; d_g = -.14, trivial).

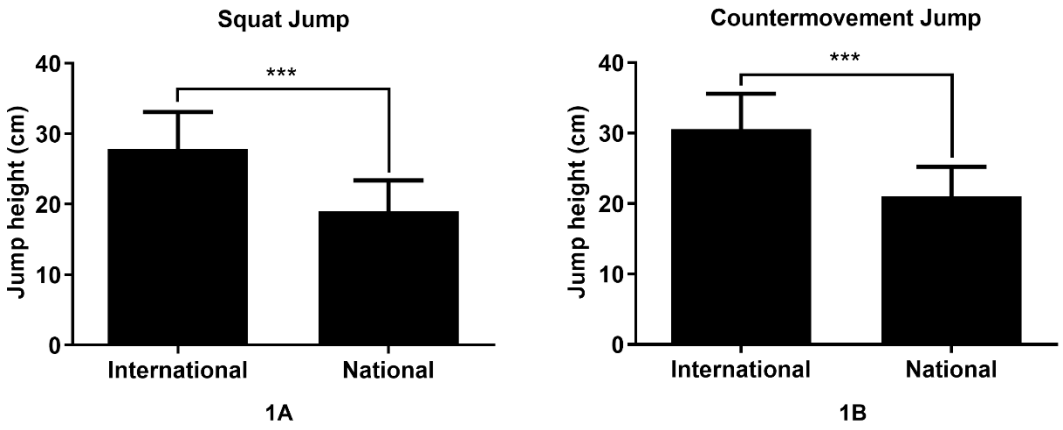

Figure 1. Vertical jump height performance on the squat jump and countermovement jumps between competitive levels (1A and 1B). *** $p < .001$.

With regard to the sport classes factor, statistically significant differences were found for the two VJ measures: SJ [$F(2,35) = 4.17$; $p = .024$; $\eta\rho^2 = .193$, medium)] and CMJ [$F(2,35) = 3.70$; $p = .035$; $\eta\rho^2 = .175$, medium)] tests. No statistically significant differences were found for EI ($p = .474$). In Table 2, there are the single scores and pairwise comparisons for the three dependent variables of this study. FT3 had better jumping performance in SJ and CMJ than FT2 players (small effect size), and FT2 jumped higher compared to FT1 (moderate effect sizes), but only statistically significant differences were observed between FT3 and FT1 players (large effect sizes). No statistically significant differences were found for the EI (small effect sizes).

Table 2. Vertical jump performance according to sport classes.

	Sport classes										Pairwise comparisons		
	Overall Sample		FT1 (n = 8)		FT2 (n = 25)		FT3 (n = 8)		*p*	$\eta\rho^2$	FT1 vs FT2	FT1 vs FT3	FT2 vs FT3
	M	SD	M	SD	M	SD	M	SD					
SJ (cm)	22.9	6.5	19.2	6	23.1	6.4	25.8	6.3	.024	.193	-.62	-1.01*	-.42
CMJ (cm)	25.2	6.6	21.7	6.5	25.5	6.3	27.7	7.0	.035	.175	-.60	-.84*	-.34
EI (%)	11.6	12.5	15.6	21	11.6	10.4	7.6	7.0	.47	.042	.30	.48	.41

M: mean, *SD*: standard deviation, SJ: squat jump, CMJ: countermovement jump, EI: elastic index, FT: cerebral palsy football sport classes; * $p < .05$.

The ANOVA model did not reveal any statistically significant difference in the interaction effects of sport classes between-group factor and the players' competitive level ($p > .05$). Figure 2 shows the results of pairwise comparisons between international vs national levels considering sport classes as individual subgroups. In the SJ test, statistically significant differences were found for the FT2 sport class [Figure 2A: (International: $M = 28.2$, $SD = 5.0$ cm vs National: $M = 18.4$, $SD = 3.2$ cm; $p < .001$; $d_g = 2.28$, large)]. Large effect sizes, without significant differences, were found for the comparison of FT1 (International: $M = 23.4$, $SD = 5.9$ cm vs National: $M = 16.8$, $SD = 4.9$ cm; $p = .137$; $d_g = 1.09$, large) and FT3 (International: $M = 30.9$, $SD = 4.7$ cm vs National: $M = 22.7$, $SD = 5.2$ cm; $p = .068$; $d_g = 1.42$, large) sport classes (Figure 2A).

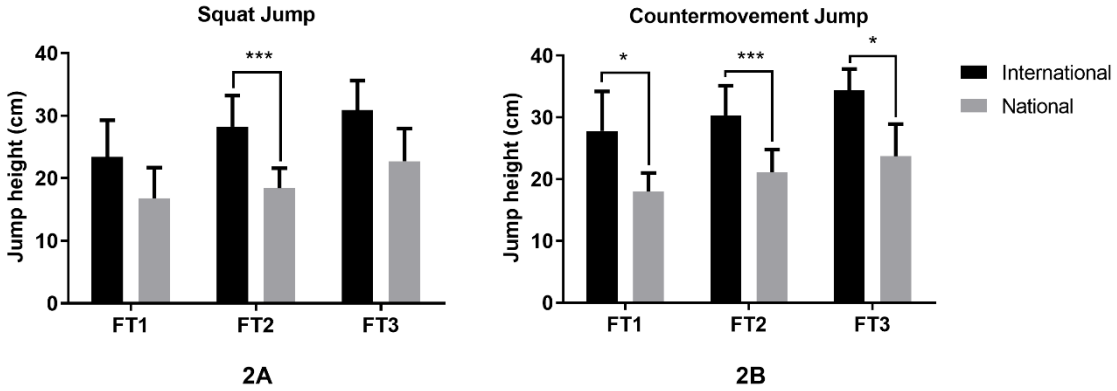

Figure 2. Vertical jump height performance on the squat jump, and countermovement jump, among player sport classes and competitive levels (2A and 2B). FT: cerebral palsy football sport classes. *** $p < .001$, * $p < .05$.

With regard to CMJ, statistically significant differences were found for the comparison between all sport classes at their respective competitive level, where the international group reached a higher jumping height than the national group: FT1 (International: $M = 27.8$, $SD = 6.4$ cm vs National: $M = 18.0$, $SD = 3.0$ cm; $p = .024$; $d_g = 1.92$, large), FT2 (International: $M = 30.3$, $SD = 4.8$ cm vs National: $M = 21.1$, $SD = 3.7$ cm; $p < .001$; $d_g = 2.09$, large), and FT3 (International: $M = 34.4$, $SD = 3.4$ cm vs National: $M = 23.7$, $SD = 5.2$ cm; $p = .021$; d_g

= 1.99, large), respectively (Figure 2B). No statistically significant differences were reported for EI in the comparison of the sport classes according to the players' competitive level in FT1 (International: *M* = 19.6, *SD* = 10.5 % vs National: *M* = 13.2, *SD* = 26.4 %; *p* = .705; d_g = .25, small), FT2 (International: *M* = 8.0, *SD* = 5.3 % vs National: *M* = 14.9, *SD* = 12.9 %; *p* = .098; d_g = -.67, moderate), and FT3 (International: *M* = 12.0, *SD* = 7.6 % vs National: *M* = 5.0, *SD* = 5.8 %; *p* = .191; d_g = .94, large).

Discussion

This study aimed to describe and compare VJ performance according to the competitive levels standard criteria and sport classes of para-footballers with CP. Overall, players with international level exhibited higher jumping performance than those belonging to a national level, and these differences are consistent across the three CP football sport classes of FT1, FT2, and FT3. Therefore, VJ assessment may offer insight into the anaerobic capability to differentiate players of different competitive levels in each player's sport classes (Reina et al., 2018; Yanci et al., 2016).

This study evidenced significant differences and large effect sizes in the VJ performance of the international versus the national level groups, providing novel evidence about the usage of VJ assessment as a discriminative parameter between footballers with CP at different competitive levels. Our results are in accordance with those reported by different researchers with footballers without impairments from the Icelandic professional league (Arnason et al., 2004), youth Spanish football players (Ruiz-Ariza et al., 2015), the under-23 Iraqi national team (Rumpf & Rodríguez, 2018), under-15 Italian football players (Trecroci et al., 2018), and Greek elite professional football teams (Kalapotharakos et al., 2006), who whom demonstrated that VJ performance is competitive level-dependent. Nevertheless, there is also contrary evidence suggesting no differences between jumping height and competitive level of football players without impairments who demonstrated a homogeneous performance in this variable (Ayarra et al., 2018; Castagna & Castellini, 2013; Cometti et al., 2001; Haugen et al., 2013; Mujika et al., 2009; Rampinini et al., 2007). In this regard, Castagna and Castellini (2013) described the difficulties in explaining the differences between competitive levels because of the different factors, such as training status or genetic factors, would provoke variations in the VJ outcomes.

More specifically, the international level group from this study obtained higher VJ height values than those obtained by Yanci et al. (2014; 2016), who studied the SJ (*M* = 20.0, *SD* = 4.3 cm – *M* = 20.45, *SD* = 4.45 cm) and CMJ (*M* = 23.9, *SD* = 5.4 cm – *M* = 24.33, *SD* = 5.37 cm) in Spanish international para-footballers with CP. In contrast, the results of our international level group were lower compared to the scores obtained by Reina et al. (2020a) in CMJ (*M* = .44, *SD* = .06 m) during a world-level tournament with international CP para-footballers from the Americas, Europe and Australasia regions. General and sport-specific reasons would explain these differences. On the one hand, some contextual factors related to players' disability should be taken into consideration (e.g., access to healthcare, training opportunities, economic resources), constraining the development of their maximum physical and physiological performance (Driscoll et al., 2013; Rumpf & Rodríguez, 2018). On the other hand, belonging to a national team that leads to international competitive experiences provokes a better development of sport-specific performance (Peña-González et al., 2021). In this vein, Wisløffet and colleagues (2004) found a strong association between maximal strength of lower limbs, sprint capacity and VJ performance in elite footballers without impairments, evidencing the relationships between parameters that have a critical contribution to sport-specific performance. Hence, the usage of VJ assessment is considered a core physical fitness aspect for determining players' selection (Dodd & Newans, 2018). Moreover, previous studies also showed a relationship between VJ height with the sprint

time (López-Segovia et al., 2011) and the maximum kicking speed (Rodríguez-Lorenzo et al., 2016) performed by football players without impairments, reinforcing the idea that VJ tests might be appropriate for assessing neuromuscular components involved when performing motor skills required in football.

The differences between international- vs national-level para-footballers were consistent across the three CP football sport classes, yet unequal between-group significant differences were found for both SJ and CMJ tests. In particular, para-footballers with the class of FT3, hence have a higher functional profile reached a superior VJ performance to FT1 players, the latter being a profile characterised by a greater impact of the physical impairment motor activities (IFCPF, 2018). In contrast, there were no statistically significant differences between FT2 and FT3 or between FT1 and FT2. These overall findings coincide with previous studies in which players with the minimum impairment criteria, such as mild impairment, for CP football exhibit significant differences compared to the other sport classes, where impairment is moderate, during VJ assessment (Reina et al., 2018; 2020a). Hence, this study provides new evidence about jumping performance in footballers with CP belonging to the new sport classes implemented worldwide by IFCPF in 2018. Despite the general trends found in this study, where FT3 was better than FT2, which in turn was better than FT1, the lack of statistically significant differences in some of the pairwise comparisons could be explained by the overrepresentation of players with unilateral spasticity profile, the most common group in this team para-sport (Reina et al., 2020b). This lack of statistically significant differences could be related to the VJ test's difficulties for discrimination between sport classes. In other words, according to Reina and colleagues (2018), horizontal jump tests could be more appropriate for classification purposes because they require relevant coordination and neuromuscular components to observe the activity limitation of CP para-footballers. In light of this, Runciman and colleagues (2016) reported that six para-athletes with unilateral spasticity, evaluated using VJ tests considering their affected and non-affected limbs after a fatigue protocol, used compensation mechanisms to counteract the deficits related to the asymmetries in muscle strength level: i.e., a higher contribution for jumping performance by the non-impaired leg. Thus, it is plausible to propose that SJ and CMJ measures could be more appropriate for analysing para-footballers' with CP neuromuscular capability and training monitoring than for classification procedures (Reina et al., 2018), since para-athletes affected by spasticity, athetosis, or ataxia present an impairment-specific constraint of the jumping ability associated with their neurological condition.

Also, with regard to the sport classes, statistically significant differences according to the competitive level were found in CMJ between FT1, FT2, and FT3 players, and in SJ only for FT2. These results coincide with Yanci et al. (2016) outcomes, suggesting that international-level para-footballers with CP could take advantage during a jump with countermovement over the SJ initiated from a static position, possibly due to the player's neuromuscular characteristics and the activity requirements of this motor task. The impaired force production and the functional deficit is partly a characteristic consequence of the altered spastic muscle structure (Mathewson & Lieber, 2015), which in the case of the jumping performance could accentuate the differences between the SJ and the CMJ expressed in the calculation of the EI (Bobbert & Casius, 2005). However, further research is necessary to explore neuromuscular features when performing VJ by footballers with CP due to the lack of significant differences found among our two between-group factors regarding the EI. From a practical perspective, coaches could consider the assessment of the VJ performance to identify footballers with CP with higher levels of neuromuscular capability as a parameter of muscle leg power in consideration of the player's sport classes. Furthermore, VJ capacity is only one parameter to consider for talent identification in

conjunction with multiple factors that are more determinants for football performance , including technical and tactical skills, anthropometric and psychological factors, environmental constraints, among other parameters (Sarmento et al., 2018).

This study has some limitations that should be addressed. Although the sample of participants is representative of the Chilean para-sport context, the number was limited in each sport class, reducing the statistical power of the analysis. Another limitation is that only the VJ capacity was measured. Other performance variables, such as maximum oxygen uptake, sprint time, agility, maximal strength, body composition, and the technical and tactical analysis would provide additional information to compare in terms of competitive levels standard criteria in footballers with CP. However, it is crucial to consider that VJ assessment is only one aspect of the multifactorial approach to football performance (Dodd & Newans, 2018; Reilly et al., 2000). Further studies should consider these observations and the possibility of assessing different VJ assessment protocols that could impact height performance and facilitate the technique execution. Moreover, future approaches could recruit female participants and a wide sample from different countries. An additional possibility is to explore a battery assessment for talent identification, considering the impairment variable and the para-sport's specific demands, which is a differential complex factor compared to regular football.

Conclusions

This study demonstrates differences in the VJ capacity performance during SJs and CMJs in para-footballers with CP from different competitive levels and according to players' sport classes. Furthermore, this suggests that footballers with CP selected to compete at the international tournament level exhibit better VJ capacity than those participating nationally. These findings provide a deeper understanding of the differences in the motor performance impairment specific to para-footballers with CP, where coaches and strength-conditioning professionals should consider VJ assessment for training monitoring and as a component for talent detection in this para-sport.

Perspectives

According to the author's knowledge, there is limited information about comparing the physical performance of para-footballers of different competitive levels. From a practical point of view, it seems that VJ assessment could be a relevant physical fitness factor that should be considered through the talent identification process. However, skills, technical, tactical, and sociological aspects that impact sports career development are factors that cannot be overlooked (Dodd & Newans, 2018). Additionally, VJ testing protocols potentially could be used throughout a competitive season to monitor players´ performance of different levels, and to assess training effects for optimizing individual´s performance. Still, it should be noted that it is necessary to contemplate the players' impairment-specific characteristics that have a relevant impact on physical performance (Reina et al., 2020a).

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