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Range of movement measurement tools to assess trunk function in wheelchair athletes with physical impairments

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Abstract: Trunk function assessment is considered a key factor for the development of evidence-based classification process in wheelchair athletes. Thus, the aim of this study was to determine the intra-session reliability of two kinematic analysis tools (2D video analysis measure and an inclinometer mobile application) that could be used by classifiers to detect trunk range of movement (ROM) impairment in wheelchair athletes. Sixteen wheelchair athletes and six non-disabled participants (CG) were recruited for this study. Wheelchair athletes were dividing according to the origin of their eligible physical impairment in a neurological impairment group (ANI, n=7) and an impaired muscle power group (IMP, n=9). ROM was assessed in sagittal and coronal plane movements. High-excellent relative intra-session reliability scores were found for trunk ROM measures for all participants (0.87 < ICC < 0.99). Significantly lower ROM values were observed in wheelchair athletes compared to CG, with the exception of the trunk flexion tilt movement measured by the 2D video analysis in the IMP group and the trunk extension tilt movement measured by the inclinometer app in the ANI group. 2D video analysis showed good intra-session reliability in the assessment of trunk ROM, while high intra-subject variability was observed when using the inclinometer app. The proposed tools may help classifiers to detect trunk ROM impairment at different levels in wheelchair athletes with different health conditions being the inclinometer app more interesting to detect lower back trunk impairment.

Keywords: range of movement; trunk; field test; inclinometer; evidence-based classification

1. Introduction

The International Paralympic Committee (IPC) Classification Code claim for the development of evidence-based classification systems for all Paralympic sports (International Paralympic Commitee, 2007), aiming to minimize the impact that the eligible impairments have on the result of the competition (International Paralympic Committe, 2015). In this process, the development of quantifiable, precise, objective, valid and reliable measures are necessary to establish the eligibility criteria for wheelchair athletes, to assess physical impairment, and to determine the impact of it on a specific sport action or movement (Tweedy & Vanlandewijck, 2011; Tweedy et al., 2014, 2018). In recent years, great amount researchers focused on the optimization of classification systems for wheelchair sports in order to establish specific functional classes profiles based on valid measures of impairment (Altmann et al., 2018; Santos et al., 2017). Nevertheless, one of the evidence-based classification process main problems is the assignment of functional classes by the classification panel during competition (Tweedy et al., 2018). Ideally, methods for classifying impairments and determining class profile are evidence-based, however current best practices require classification panels to assign a class by subjectively considering outcomes from the impairment assessment and sport specific tasks (Tweedy et al., 2018). Therefore, reliable, and objective measures that could be used during the classification process are needed.

Trunk function is considered as a key factor for an effective functional classification system in wheelchair sports (i.e., wheelchair basketball or wheelchair rugby) (Altmann et al., 2017; Santos et al., 2017; Vanlandewijck et al., 2011). Trunk range of movement (ROM), postural control or muscle strength are determining factors of trunk function, which seem to influence the sports actions performance. In this regard, previous research had reported that trunk impairment determine proficiency in wheelchair team sports, affecting specific sports actions as tilting chair, acceleration or sprint (Altmann et al., 2017, 2018; Saltan & Ankarali, 2017). Thus, the classification processes must include measures as functional observation of active trunk movement, in terms of volume of trunk action, (IWBF, 2018) or manual muscle tests to assess trunk range of motion (IWRF, 2015), to separate athletes with different impairment level into sport classes. For example, wheelchair athlete's evaluation includes the assessment of trunk movement in the sagittal, coronal and the transverse plane in real surroundings (players' observations on the court in a sports wheelchair with straps) (IWBF, 2014). However, this evaluation is subject to the classifier's opinion, hence, objective measures are needed to assess trunk movement supporting classifiers work in evidence-based classification process.

The complexity of developing evidence-based classification systems is widely related to the number of eligible impairment types (Tweedy et al., 2014). Wheelchair sports classification systems include different eligible physical impairments (e.g., impaired strength, hypertonia, impaired range of movement, limb deficiency…) involving athletes with different health conditions. The trunk stability and ROM trunk deficits in wheelchair athletes who present a neurological health condition (i.e. cerebral palsy) is determined by a deficit in voluntary trunk muscle control affecting postural control (Roldan et al., 2020). Additionally, the presence of other physical impairments (hypertonia, ataxia, and athetosis) could affect trunk muscles coordination affecting dynamic trunk control (Barbado et al., 2019; Heyrman et al., 2013; Kallem Seyyar et al., 2019). On the other hand, athletes with physical impairments, derived from health condition such as spinal cord injury (SCI) or limb deficiency, present an impaired voluntary motor control below the level of the injury (Kirshblum et al., 2011) affecting the motor functions of the musculature involved and favoring greater functionality of the unaffected musculoskeletal structures of the trunk (Serra-Añó et al., 2013).

With the current development of adapted sport, the new classification systems include a greater number of impairments as eligible (Tweedy et al., 2014). Consequently, it is necessary to provide specific tests that allow an objective and reliable assessment of the trunk movement function in wheelchair athletes with different physical impairments, that can be used by classifiers during the classification process to assess trunk movement impairment.

To address the gaps raised above, we have purpose two kinematic analysis tools that can be used in a complementary way to assess trunk ROM (2D video analysis measure and an inclinometer mobile application) on evidence-based classification process in wheelchair athletes to assess different levels of trunk impairment. The aim of this study was threefold: a) to determine the intra-session reliability of the proposed measures in wheelchair athletes with physical impairments, b) to analyze the differences in the ROM values recorded by the tools depending on the impairment nature; and c) to compare ROM values differences between wheelchair athletes depending on the origin of their impairment.

2. Materials and Methods

Subjects — Sixteen wheelchair athletes with different physical impairments and six non-disabled participants were recruited for this study. Wheelchair athletes were recruited from three regional clubs of wheelchair basketball, wheelchair slalom and paratriathlon respectively and were splited into two sub-groups according to the origin of their eligible impairment. Seven athletes with spastic and mixed forms of cerebral palsy (CP) (age = 32 ± 10 years; sitting height = 148 ± 16 cm; body mass: 70 ± 14 kg) composed the sub-group of athletes with neurological impairment (ANI). Participants with medical conditions such amputation (n=2), incomplete lumbar SCI (n = 3) and spina bifida (n = 4) comprised the impaired muscle power sub-group (IMP) (age = 36 ± 11 years; sitting height = 163 ± 11 cm; body mass = 74 ± 19 kg). Six non-disabled participants comprised the control group (CG) (age = 30 ± 4 years; sitting height = 143 ± 7 cm; body mass = 68 ± 7 kg).

Inclusion criteria were determined as having an experience of at least three years in their sport and having no other health problems apart from those derived from their physical impairment. All participants trained at least three times a week and were competing at national level. Additionally, all participants had to be able to independently maintain an unsupported sitting position. All participants signed an informed consent form after being informed about the aims and procedures of the experiment and participated voluntarily. The study was conducted according to the Declaration of Helsinki, and the protocol was fully approved by the ethics committee of the authors' university.

Experimental design — A cross-sectional design was carried out to assess the intra-session reliability of two kinematic analysis tools to assess trunk ROM (2D video analysis measure and an inclinometer mobile application) and to identify trunk ROM impairment in wheelchair athletes. Testing was conducted over one single session. The participants carried out a standardized warm-up that consisted of performing dynamic trunk movements for 2 min. Test procedure was explained during the warm-up period, performing 2 repetitions of each movement.

Methodology — Participants were asked to perform four trunk movements, three repetitions each: trunk flexion (TF), trunk extension (TE), trunk right lateral flexion (TRL) and trunk left lateral flexion (TLL). These movements were performed with participants seated on a table with feet set on the floor at 90° knee flexion. The resting periods between each of the four movements where 60 seconds long and 15 seconds between repetitions in each trunk movement. The para-athletes were instructed to perform each movement with upper limb crossed over their chest with a neutral position of the shoulders, with their maximal engagement in each movement until they knew that the movement was active, controlled and performed without compensation. In each movement tested, participants were instructed to reach in a controlled way as far as possible before returning to their initial position.

2D video analysis — Two video cameras (Panasonic, Lumix, FZ20) were ubicated frontally and laterally 4 m from the participant, and movements were recorded with a frequency of 200 Hz. The free software Kinovea™ (v.0.8.15., www.kinovea.org) was used to the ROM analysis. Regarding this, 6 markers (10.9 mm) were ubicated on the participants in the following anatomic points: one on the sternum manubrium (ME), bilaterally on the iliac spines (EI_1, EI_2), one on the seventh cervical vertebra (C7) one on the twelfth thoracic vertebra (T12) and another on the first vertebra of the area sacral (S1) (Kolber et al., 2013). For the calculation of

ROM in the sagittal plane, the angle obtained between the horizontal axis and the trunk segment between C7-S1 was recorded, while for the analysis of the coronal plane, the angle obtained between the horizontal axis and the segment between the midpoint of EI_1-EI_2 and ME was recorded.

Inclinometer mobile application (app) — The free app *i Handy level* (Jayavel et al., 2017) was used in an Android smartphone to measure the trunk ROM in sagittal and coronal planes. Before starting measurements, the app was calibrated with a level surface. The app acts as a digital inclinometer from the accelerometer sensor integrated in the smartphone, allowing to know the inclination degrees on the horizontal axis (de Brito Macedo et al., 2019). The smartphone was positioned on the participants in their area between T12 and S1 (Jayavel et al., 2017; Kolber et al., 2013).

Statistical Analysis— The results were presented as mean and standard deviation (SD). The normality of the sample was calculated using the Saphiro-Wilk test, while the Levene test was used to check the homogeneity of the variances. Non-parametric tests were used for the analysis of the variables. Relative and absolute reliability among trials in each test measure was assessed using intra-class correlations (ICCs) and standard error measurement (SEM) respectively. Intra-session reliability was calculated as the immediate test-retest reliability related to the random variability of the measurement per se that could be subject to the inaccuracy of the measurement or athlete's performance variations. ICC values were calculated and categorized as excellent (0.90–1.00), high (0.70–0.89), moderate (0.50–0.69), or low (< 0.50) (Fleiss, 1986; Hopkins, 2017). The SEM was calculated using the following formula: $SEM = SD\sqrt{1 - ICC}$ and expressed as a percentage of the mean scores (SEM%) considering values lower than 10% as acceptable.

The Wilcoxon signed rank test was used to analyze trunk ROM values differences between the two kinematic analysis tools. A one-way analysis of variance (ANOVA) with Bonferroni's *post hoc* was used to examine trunk ROM mean differences among each group. For those variables that did not comply with the homoscedasticity assumption Welch correction were applied, followed by Games-Howell *post hoc* tests. The Hedges' g index (dg) was used to calculate the effect sizes of between-group differences (Hedges & Olkin, 1985). This index is based on Cohen's index (Cohen, 1998) but provides an effect size estimation when reducing the bias caused by small samples ($n < 20$). Hedge's g was interpreted as: large ($dg > 0.8$), moderate ($0.5 < dg \leq 0.8$), small ($0.2 < dg \leq 0.5$) and trivial ($dg < 0.2$). Statistical analysis was performed with the Statistical Package for Social Sciences program (SPSS® Inc, version 25.1 Chicago, IL, USA). The level of statistical significance was established at $p \leq 0.05$.

3. Results

Within-session reliability for each player was evaluated among three trials performed for each kinematic analysis measure (Table 1). High-excellent relative intra-session reliability scores were found for trunk ROM for the ANI, IMP and CG groups ($0.87 < ICC < 0.99$) and absolute reproducibility show acceptable scores of SEM (< 8.74%) for the 2D video analysis tool. On the other hand, in spite of the inclinometer app show high-excellent relative reliability ($0.74 < ICC < 0.98$) for all participants, higher SEM values were obtained for the ANI (SEM < 16.45%) and IMP (SEM < 17.51%) while CG absolute reliability was SEM < 9.5%.

In Table 2, the differences between ROM values for the two kinematic tools are reported. Trunk ROM values measured from the 2D video analysis tool were higher for the sagittal and coronal movements compared to the inclinometer app. However, no significant ROM differences ($p > 0.05$) were found for the ANI in the sagittal plane movement (TF and TE) and for the CG in the TF movement.

The differences of trunk ROM between each group in the two planes of movement for each kinematic analysis tool are presented in Table 3. Wheelchair athletes (ANI and IMP) show significant lower ROM values in comparison with CG ($p < 0,05$; $-2.73 < dg < -1.23$) in all movements except for the TF measured with 2D video analysis when compared IMP and CG, and for the TE measured with inclinometer app when compared ANI and CG. No significant differences ($p > 0.05$) were found between wheelchair athletes with different impairments (ANI and IMP).

Table 1. Intrasession reliability for range of movement tools (2D video analysis measure and inclinometer mobile app).

	Trunk movement	2D-VA ICC (95% IC)	2D-VA SEM%	MIA ICC (95% IC)	MIA SEM%
ANI	TF	0.96 (0.81, 0.99)	6.10	0.96 (0.78, 0.99)	14.03
IMP		0.98 (0.93, 1)	5.16	0.99 (0.95, 1)	6.23
CG		0.88 (0.52, 0.98)	2.90	0.90 (0.57, 0.98)	9.50
ANI	TE	0.89 (0.48, 0.98)	8.74	0.87 (0.44, 0.98)	16.45
IMP		0.98 (0.91, 1)	6.71	0.98 (0.91,1)	10.98
CG		0.98 (0.90, 1)	3.10	0.97 (0.86, 1)	7.40
ANI	TRL	0.91 (0.59, 0.98)	7.18	0.99 (0.94, 1)	7.75
IMP		0.99 (0.98, 1)	4.64	0.96 (0.85, 0.99)	12.49
CG		0.98 (0.92, 1)	3.40	0.98 (0.88, 0.99)	3.90
ANI	TLL	0.87 (0.41, 0.98)	6.48	0.99 (0.98, 1)	14.05
IMP		0.98 (0.93, 1)	6.29	0.84 (0.40, 0.94)	17.51
CG		0.98 (0.91, 1)	5.30	0.87 (0.49, 0.98)	12.10

2D-VA = 2D video analysis tool; MIA = mobile inclinometer application; ICC = intra-class correlations; IC = interval confidence; SEM = standard error measurement; ANI = athletes with neurological impairment; IMP = impaired muscle power sub-group; CG = control group; TF = trunk flexion; TE =trunk extension; TRL = trunk right lateral flexion; TLL = trunk lateral left flexion.

Table 2. Trunk range of movement mean differences between 2D video analysis measure and mobile inclinometer application.

	Trunk movement	(Mean ± SD) 2D-VA	(Mean ± SD) MIA	Mean difference (%)	dg (95% CI)
ANI (n=7)	TF	36.43 ± 10.18	30.71 ± 18.88	15.70	0.35 (-0.70 / 1.41)
	TE	30.57 ± 6.19	20.43 ± 17.35	33.17	0.72 (-0.36 / 1.81)
	TRL	29.14 ± 6.96	11.57 ± 5.74*	60.30	2.56 (1.15 / 3.97)
	TLL	24.71 ± 3.73	13.71 ± 2.36*	44.52	3.28 (1.67 / 4.88)
IMP (n=9)	TF	45.44 ± 15.63	25.89 ± 18.14*	43.02	1.10 (0.11 / 2.09)
	TE	35.89 ± 16.01	13.11 ± 6.41*	63.47	1.78 (0.69 / 2.87)
	TRL	27.33 ± 13.04	16.00 ± 10.40*	41.46	0.91 (-0.06 / 1.89)
	TLL	26.44 ± 13.05	15.89 ± 5.01*	39.90	1.02 (0.03 / 2.00)
CG (n=6)	TF	55.83 ± 3.06	55.50 ± 8.48	0.59	0.05 (-1.08 / 1.18)
	TE	76.83 ± 10.53	29.33 ± 6.86*	61.82	4.93 (2.66 / 7.21)
	TRL	45.33 ± 7.29	27.67 ± 5.35*	38.96	2.55 (1.03 / 4.07)
	TLL	45.5 ± 10.90	26.67 ± 4.93*	41.38	1.95 (0.57 / 3.32)

SD = standard deviation; 2D-VA = 2D video analysis tool; MIA = mobile inclinometer application; dg = Effect size; CI = confidence interval; ANI = athletes with neurological impairment; IMP = impaired muscle power sub-group; CG = control group; TF = trunk flexion; TE =trunk extension; TRL = trunk right lateral flexion; TLL = trunk lateral left flexion; * Significant level set at $p < 0.05$; ** Significant level set at $p < 0.01$.

Table 3. Differences in the trunk range of movement mean values among each group for the two different tools.

		dg (95% CI)		
	Trunk movement	ANI - IMP	ANI - CG	IMP - CG
2D-VA	TF	-0.64 (-1.65, 0.37)	-0.80 (-1.88, 0.27)	-2.34 (-3.76, -0.93)*
	TE	-0.40 (-1.40, 0.59)	-2.73 (-4.15, -1.31)*	-5.15 (-7.41, -2.89)*
	TRL	0.13 (-0.86, 1.12)	-1.50 (-2.67, -0.34)*	-2.17 (-3.54, -0.80)*
	TLL	-0.17 (-1.16, 0.82)	-1.46 (-2.62, -0.30)*	-2.50 (-3.95, -1.04)*
MIA	TF	0.25 (-0.74, 1.24)	-1.87 (-3.10, -0.64)*	-1.55 (-2.80, -0.31)*
	TE	0.54 (-0.46, 1.55)	-2.31 (-3.63, -0.99)*	-0.61 (-1.73, 0.50)
	TRL	-0.46 (-1.46, 0.54)	-1.23 (-2.36, -0.11)*	-2.65 (-4.14, -1.16)*
	TLL	-0.46 (-1.46, 0.54)	-2.05 (-3.32, -0.78)*	-3.24 (-4.90, -1.59)*

2D-VA = 2D video analysis tool; MIA = mobile inclinometer application; dg = Effect size; CI = confidence interval; ANI = athletes with neurological impairment; IMP = impaired muscle power sub-group; CG = control group; TF = trunk flexion; TE =trunk extension; TRL = trunk right lateral flexion; TLL = trunk lateral left flexion; * Significant level set at $p < 0.05$; ** Significant level set at $p < 0.01$.

4. Discussion

The aim of this study was threefold: a) to determine the intra-session reliability of the proposed measures in wheelchair athletes with physical impairments, b) determine the differences in the ROM values recorded by the tools used; and c) analyze ROM values differences between wheelchair athletes depending on the origin of their impairment. The main results of this study showed high measurement reliability when using the video analysis tool (2D), while the inclinometer app reflected high within-subject variability in athletes with physical impairments. In addition, it was observed that the ROM values obtained in the sagittal and coronal plane differ when using the two tools simultaneously. On the other hand, significantly lower ROM values were observed when the 2D video analysis was used in athletes with physical impairments (ANI and IMP) compared to CG, except for TF movement, when comparing IMP to CG; as well as in the TE movement measured by the inclinometer app when comparing ANI with respect to CG. No significant differences were found in trunk ROM values among athletes with physical disabilities regardless of the origin of their impairment.

Trunk ROM assessment is a key factor in the classification process for the allocation of functional classes, mainly in athletes with physical impairments which affect the functionality of the trunk in sports such as basketball and wheelchair rugby (Altmann et al., 2018; Saltan & Ankarali, 2017). In the rehab field, video analysis tools (i.e., 2D) (Cunha et al., 2019; Kuo et al., 2009; Sánchez et al., 2017) and mobile app base on goniometry (de Brito Macedo et al., 2019; Keogh et al., 2019; Pourahmadi et al., 2016) have proven to be reliable tools as an alternative to more sophisticated devices for the assessment of trunk functionality in people with different levels of impairment. In addition, video analysis tools (i.e., 2D) have been recognized as reliable tools to assess the functionality of different segments of the spine (Sánchez et al., 2017), however, in this study the trunk is analyzed as a single segment as it is evaluated during the classification process (IWBF, 2014; IWRF, 2015). In this sense, to date, no reliability studies that could be compared with the values obtained in this study (0.87 < ICC < 0.98; SEM < 8) have been conducted. For the inclinometer app, excellent-high relative reliability values were shown (0.74 < ICC < 0.98), similar to those obtained by Brito Macedo et al. (2019) when using the *i Handy level* app (0.8 < ICC < 1) in the ROM analysis in patients with chronic back pain. However, for wheelchair athletes, trunk flexion and extension movements showed low absolute reliability values, which suggests greater within-subject variability for sagittal plane measurement.

ROM values recorded in the sagittal and coronal planes showed significant differences for most of the variables analyzed with the two measurement tools, obtaining higher angles with the 2D video analysis ($p < 0.05$; $0.91 < dg < 4.93$). In this sense, for the ANI group, values of 29.14 ± 6.96º and 24.71 ± 3.73º were observed for the lateral movements in the coronal plane for the TRL and TLL movements respectively, through the 2D video analysis, while values of 11.57 ± 5.74º and 13.71 ± 2.36º in the TRL and TLL movements respectively were obtained with the inclinometer app. Considering the different protocols applied, these differences could be justified by the difference in the trunk segment analyzed with each measurement tool. Given the placement of the smartphone on T12-S1, the inclinometer app assessed the ROM angle of the spine at the lumbar level (Kolber et al., 2013), while in the 2D video analysis, the assessed segment took in consideration the upper thoracic mobility, registering higher angles of movement. However, no differences were found when comparing the variables TF and TE in the ANI group ($p > 0.05$; $0.35 < dg < 4 .72$), which could be due to the deficit in voluntary muscle control and the global alteration of the trunk postural control mechanisms in this group due to their neuromuscular impairment.

This condition could be reflected in a lower dissociation between the trunk structures (Heyrman et al., 2013; Kallem Seyyar et al., 2019), affecting the control and trunk ROM, both at the lumbar and thoracic level and therefore, obtaining similar values when using the two tools. On the other hand, these differences were significant for all movement variables in the IMP group. These athletes presented less affectation at the thoracic level, given the characteristics of their health condition (e.g., spinal cord injury at the lumbar level), which led to obtaining higher ROM values when using 2D video analysis regarding to those obtained through the inclinometer app. Finally, while in CG higher ROM values were obtained in the TE, TRL and TLL tilt movements, no differences were found in TF, probably due to the maximum possible tilt achieved both at the lumbar and thoracic level in this movement.

During of developing classification systems based on scientific evidence, in addition to applying measures and tools that allow a valid detection of deficiency in athletes with different impairments, an application of these measures is required in a population without deficiency in order to get normalized values to compare the results with (Tweedy et al., 2014). The comparisons made in the present study showed significant differences in all the variables analyzed when comparing ANI and IMP independently with respect to CG, which did not show impairment of trunk functionality. The results obtained showed that both measurement tools are able to detect a impaired trunk ROM in the two groups ($p < 0.05$; $-2.73 < dg < -1.23$) given the affectation at the level of the trunk that causes the deficiency in these athletes with physical impairments (Serra-Añó et al., 2013). However, two exceptions to these differences were found. When comparing ANI and CG, the TE variable did not show significant differences for the analysis of trunk ROM with the inclinometer app, which means a lesser involvement of the ANI group at the lumbar level in the execution of the posterior movement. On the other hand, no significant differences were reported in the TF tilt movement measured by 2D video analysis between the IMP and CG groups, above all, because the low involvement of IMP at the thoracic level will be reflected in a higher trunk ROM value when compared to this tool. On the other hand, no differences were found in trunk ROM between the two groups with impairments analyzed, which indicates that the origin of the deficiency has not determined a greater or lesser trunk ROM, probably due to the different level of affectation within each group (Altmann et al., 2017).

The main limitation of the study is the low sample size, which makes it difficult to establish levels of trunk impairment within each group of athletes with different health conditions. Furthermore, since there are no studies that have used 2D video analysis in the assessment of trunk ROM in a global way, it has not been possible to compare the values obtained with previous research. On the other hand, even though good intra-session reliability values have been obtained, the inclinometer app showed high intra-subject variability in athletes with physical disabilities. For future studies, it would be convenient to assess test-retest reliability including more trials to ensure test accuracy. Given the great utility that the use of this type of tools can entail during the classification process, a further study in this area is recommended, as well as a study in which intersessional reliability is analyzed.

5. Practical Applications.

In summary, the 2D video analysis showed good intra-session reliability in the assessment of trunk ROM in wheelchair athletes with physical impairments, while high intra-subject variability was observed when using the inclinometer app. Thus, 2D video analysis provides a reliable and low-cost measure to assess trunk ROM in wheelchair athletes supporting classifiers work in evidence-based classification process, whilst inclinometer app should be more investigated in this population.

The proposed tools in this study allow to detect trunk impairments in the coronal plane differing between athletes with physical impairment and non-disabled people. However, to assess sagittal plane movements, inclinometer app measure could be more interesting to detect lower back trunk impairment in athletes with health conditions as spinal cord injury or spina bifida. Therefore, the proposed tools could be used independently or complementary to assess both lumbar spine ROM and upper thoracic mobility detecting different trunk function level impairment according to the minimal eligibility criteria stablished for a specific wheelchair sport.

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