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A new reliable device to assess trunk extensors strength

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Purpose: This study aimed to examine the reliability of trunk extensor strength assessment with a functional electromechanical dynamometer (FEMD). *Methods*: Thirty-one men performed strength assessment at different velocities (V) (V_1 = 0.15 m·s^{-1}, V_2 = 0.30 m·s^{-1}, V_3 = 0.45 m·s^{-1}) and range of movement (R) (R_1 = 25% cm; R_2 = 50% cm), and isometric contraction at 90º. Reliability was obtained through the intraclass correlation coefficient (ICC), typical error (TE), and coefficient of variation (CV). *Results*: The absolute reliability provided stable repeatability of the average eccentric strength in the V_1R_1 condition (CV = 9.52%) and the maximum eccentric strength in V_1R_1 (CV = 9.63%) and V_2R_2 (CV = 9.66%). The relative reliability of the trunk extensor's average strength was good (ICC = 0.77–0.83) for concentric and good (ICC = 0.78–0.85) and moderate (ICC = 0.67–0.74) for eccentric contraction. Also, good (ICC = 0.77–0.81) and moderate (ICC = 0.55–0.74) reliability of the maximum strength were obtained for concentric and eccentric contraction. The most reliable manifestation to evaluate the concentric (CV = 11.33%) and eccentric (CV = 9.52%) strength was the average strength in the V_1R_1 condition and the maximum strength (CV = 10.29%) to isometric assessment. The average concentric strength in the V_2R_2 condition (r = 0.69) and the maximum eccentric strength in the V_1R_1 condition (r = 0.65) were the best related to the maximum isometric strength. *Conclusions*: FEMD is a highly reliable device to evaluate trunk extensors strength.

Key words: *isokinetic, core, strength, reproducibility, dynamometer*

1. Introduction

Muscle strength is one of the fundamental parameters for human movement, with a crucial role in sports performance and injury prevention [42]. Specifically, in the spine, the muscles are part of the active subsystem, and together with the passive subsystem (vertebrae, discs, and ligaments) and the neural subsystem (nerves and central nervous system) are responsible for maintaining and recovering stability after a disturbance [37]. This way, trunk strength plays a vital role in various aspects related to health [16], [28], sport [3], [45], and injury prevention [1]. Thus, the weakness or imbalance of trunk muscles has been associated with the occurrence and severity of low back pain [6], [31].

In conjunction with the rest of the trunk muscles, the erector spine and lumbar multifidus stabilize the lumbar spine by controlling segmental movement and increasing joint stiffness [32]. In addition, these muscles have the function of extending the trunk [32], eccentrically controlling trunk flexion [15], and limiting trunk movement during gait. Hence, its function is relevant in most human activities [36], [43]. Because of their importance, weakness in these muscles

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could lead to changes in lumbar stability, increasing the stress on passive tissues with the potential risk of injury or lumbar pain [14], hence, knowing the strength levels of these muscles is paramount from both a performance and health standpoint.

Maximum trunk strength has been measured using different devices, such as hand-held dynamometers [13], [35] and isokinetic dynamometers [27], [40]. However, isokinetic devices have been questioned because they do not necessarily represent the physiology or velocity of natural movement in their evaluation [4]. In addition, they are not universally available due to their high cost, low portability and space limitations [44]. With the advancement of technology, new multi-joint dynamometers have been developed to offer a more natural approach than classic dynamometers [13], such as the functional electromechanical dynamometer (FEMD). The FEMD allows a wide variety of movements (isokinetic, isotonic, elastic, isometric, inertial, eccentric, and vibration) [39]. Due to these characteristics, it has been used previously to evaluate the upper extremities [33], lower extremities [24], [25] and trunk flexors [38]. From our point of view, this device has at least two significant advantages over the devices used to date. Firstly, the evaluation of strength can be carried out more functionally and, secondly, the cost of this device is lower than the traditional isokinetic machines. In addition, the FEMD offers different strength variables that can be used for assessment and its ease of use and transport makes it a new and more convenient tool for evaluation in medical or sports environments [26].

Due to the importance of the lumbar extensor muscles, developing reliable methods for measuring strength is essential. Reliability refers to the repeatability or reproducibility of measurement; thus, the higher the reliability, the less error and the better measure [19]. Atkinson and Nevill emphasize the importance of reliable measurements in sports medicine and research [2]. Thus, once the reliability and validity have been established, the professional could determine if the observed changes in human performance result from the interventions applied or simply an inconsistency inherent in human performance [5].

In addition to this, it is essential to have evaluations that reflect the strength of the lumbar extensors without the intervention of the hip extensors [30] since the latter can produce greater activation at different torque and velocities [7]. Likewise, it is challenging to differentiate between muscle groups if the pelvis is not stabilized during measurement [9]. In addition, higher isokinetic velocities have been associated with higher measurement error, i.e., lower reproducibility [5]. Given the above, the position to be evaluated, the velocities and the equipment to be used are essential to avoid erroneous conclusions regarding the lumbar extensors' function or dysfunction. Thus, examining if this new generation of dynamometers is reliable for assessing lumbar extensors may be helpful in both sports and healthcare settings.

To our knowledge, the trunk extensors' strength has not yet been investigated with this device, hence, we do not know its reliability. Therefore, the main purposes of this study were (I) to examine the absolute and relative reliability of trunk extensor strength with a FEMD and to determine the most reliable assessment conditioning, (II) to compare the absolute and relative reliability of average strength and maximum strength of trunk extensors and (III) to determine which isokinetic condition of evaluation is best related to the maximum isometric. We hypothesized that (I) low velocities and short range of movement would be more reliable than high velocities and a large range of motion. Additionally, we hypothesized that (II) average strength was a more reliable variable than maximum strength in trunk extensors evaluation and that (III) slow velocities are best suited to isometric evaluation. The results are expected to provide new information regarding trunk strength evaluation protocols using FEMD.

2. Materials and methods

2.1. Participants

A convenience sample of thirty-one healthy young men without experience in isokinetic or dynamometers devices volunteered to participate in this study (Table 1). Participants were recruited from the university community. To participate in the study, subjects had to be physically active, with Oswestry Low Back Pain Disability scores less than 20% because higher scores have been associated with more significant isokinetic strength variability [21]. Participants who had a history of neurological or cardiorespiratory pathology, musculoskeletal injuries or abdominal surgeries within the last six months and performed specific trunk exercises were excluded from the study. Furthermore, they were informed regarding the nature, aims and risks associated with the experimental procedure before giving their written consent to participate. The study protocol was approved by the Institutional Review Board of the University of Granada

(No. 350/CEIH/2017) and was conducted following the Helsinki Declaration.

2.2. Study design

A repeated-measurement design was used to evaluate the trunk extensor's strength with different protocols. To minimize the typical error, subjects first attended a two-familiarization session on two days (at least 48 hours apart). Then, participants completed different conditioning of velocity (V) and range of movement (R) protocols on each testing day. All evaluations were conducted by sports science research (AR-P), who had extensive experience performing muscle strength testing's and using the device. The rater was blind to the results of their measurements and additional cues that were not part of the test. In addition, the assessment was performed at the same time of the day (± one hour) and under the same environmental conditions (~21 °C and ~60% humidity).

2.3. Testing procedures

Isometric and isokinetic trunk extensors strength was measured with a FEMD (Dynasystem, Model Research, Granada, Spain) [39], using different V and R. The isometric strength was measured at 90° of the trunk to the thigh. Velocities used were: V_1 (0.15 m·s^{-1}), V_2 (0.30 m·s^{-1}), and V_3 (0.45 m·s^{-1}).

The distance between the greater trochanter to acromion was measured to calculate the R following the International Society for the Advancement of Kinanthropometry protocols [41], with a SECA® tape measure. The total distance was considered 100%, from which 25% (R_1) and 50% (R_2) were calculated for each participant. This R measurement was registered in the FEMD configuration to program the execution of the measurement.

The extensors' strength was measured in a sitting position. For this purpose, the participants sat with their trunks at 90° on a bench with their arms crossed on their chest, knee flexion, and feet on the floor (Fig. 1). Straps stabilized the pelvis position to avoid the involvement of other muscles, such as the gluteus maximus or any displacement on the bench. Despite the fixation, the position was comfortable. In addition, the knee flexion reduced hamstring tension, favoring the lumbopelvic kinematics and reducing biomechanical stress [23]. The seated 90° position was measured with a goniometer (Baseline). Two FEMD familiarization sessions were performed, separated by 48 hours. They consisted of a general warm-up (five minutes of jogging at <130 beats per minute (Polar M400), five minutes of joint mobility, and three sets of 15 repetitions of front planks and gluteal bridges) followed by four sets by five repetitions on the FEMD (two submaximal and three maximal) at a velocity of 0.15 m·s^{-1} and 0.45 m·s^{-1} with a short R (R_1 = 25%) and a large R (R_2 = 50%). Between each set, there was a three--minute rest.

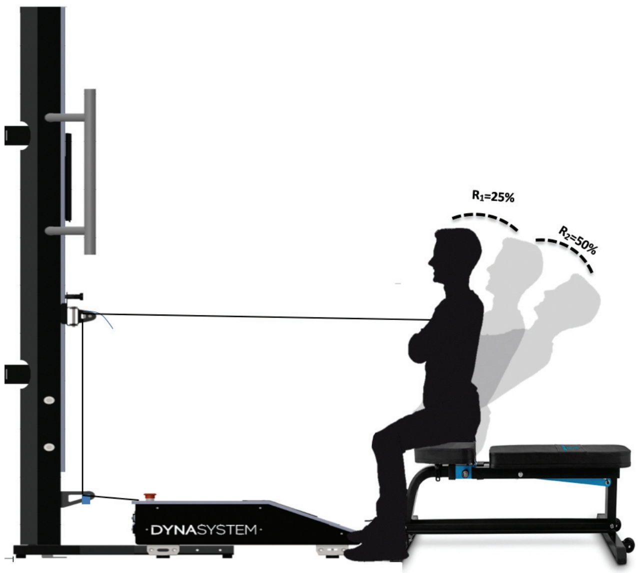

Fig. 1. Participant performing a maximum effort of trunk extension in the FEMD with different R (R_1 = 25% cm; R_2 = 50% cm)

For the evaluation, the warm-up was repeated and a five-minute rest period was given before starting the procedure. The test consisted of three series of four maximum consecutive repetitions of trunk extensors at V_1R_1 (0.15 m·s^{-1}, 25% cm), V_2R_1 (0.30 m·s^{-1}, 25% cm), V_3R_1 (0.45 m·s^{-1}, 25% cm), V_1R_2 (0.15 m·s^{-1}, 50% cm), V_2R_2 (0.30 m·s^{-1}, 50% cm) and V_3R_2 (0.45 m·s^{-1}, 50% cm). The pause between sets was 3-minute. After that, a maximum isometric contraction of five seconds in a seated 90° position was performed: V_0R_{90} (0 m·s^{-1}, 90°). The test and retest were performed within 48 hours of each other. The order of the velocities and range of movements was randomly established. This order was carried out in the two testing sessions.

2.4. Data analysis

The three highest repetitions of the average strength and the maximum strength for the concentric and eccentric contraction were taken to calculate the dynamic strength. For calculating the isometric strength, the average strength and maximum strength of the repetition were taken.

2.5. Statistical analysis

The descriptive data are presented as mean (SD). The Shapiro–Wilk normality test verified the distribution of the data. *T*-tests of paired samples assessed the reliability with the effect size (ES). The scale used for interpreting the magnitude of the ES was: negligible (<0.2), small (0.2–0.5), moderate (0.5–0.8), and large (≥0.8) [8]. Absolute reliability was assessed using the typical error (TE) and coefficient of variation (CV), while relative reliability was assessed using the ICC, model 3.1, with their respective 95% confidence intervals (CI). The ICC was interpreted as follows: <0.50 – poor, between 0.50 and 0.75 – moderate, between 0.75 and 0.90 – good, above 0.90 – excellent [29]. The following criteria were used to determine acceptable (CV ≤ 10%, ICC ≥ 0.80) and high (CV ≤ 5%, ICC ≥ 0.90) reliability [22]. A Pearson correlation coefficient (r) was used to assess the relationship between the isometric and dynamic tests. The criteria to interpret the magnitude of the r were small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), extremely large (0.90–1.00) [20]. Reliability analyses were performed using a customized spreadsheet [18], while the JASP software package (version 0.14.1) was used for all other analyses.

The sample size was similar to previous studies aimed to examine the reliability of isokinetic and isometric trunk extensor muscle strength [10], [12], [17], [27], [40].

3. Results

The characteristics of the participant are displayed in Table 1. No participant dropped out of the study due to pain or failure to attend an evaluation test.

Table 1. Demographic characteristics of the participants

Variables	Mean (SD)
Age [years]	21.5 (2.0)
Body mass [kg]	69.9 (7.0)
Height [m]	1.7 (0.1)
BMI [kg/m^2]	23.0 (1.6)
OLBPD [%]	2.8 (3.7)
ROM 100% [cm]	51.5 (3.5)
ROM 25% [cm]	12.9 (0.9)
ROM 50% [cm]	25.8 (1.8)

SD – standard deviation, ROM – range of movement, BMI – body mass index, OLBPD – Oswestry low back pain disability.

In Tables 2 and 3, the mean ± SD, ES, CV, TE and ICC of the average and maximum strength for the trunk extensors are presented. The results indicate no

Table 2. Test-retest reliability of average strength measurements [kg] provided by the FEMD at different velocities and ranges of movements

Conditions		Day 1	Day 2	p-value	ES	CV (95% CI)	TE (95% CI)	ICC (95% CI)
ISO	$V_0R_{90°}$	72.3 (20.3)	75.0 (19.4)	0.342	0.13	14.62 (11.68–19.54)	10.77 (8.61–14.39)	0.72 (0.49–0.85)
CON	V_1R_1	62.1 (15.9)	65.6 (16.0)	0.065	0.22	11.33 (9.05–15.14)	7.23 (5.78–9.67)	0.81 (0.63–0.90)
	V_2R_1	54.1 (16.3)	62.9 (17.0)	0.009	0.53	12.18 (9.73–16.28)	7.12 (5.69–9.52)	0.83 (0.67–0.91)
	V_3R_1	52.7 (18.0)	59.1 (15.2)	0.004	0.38	14.24 (11.38–19.03)	7.96 (6.36–10.64)	0.78 (0.60–0.89)
	V_1R_2	60.5 (18.0)	61.2 (15.7)	0.698	0.05	12.59 (10.06–16.83)	7.66 (6.12–10.24)	0.80 (0.63–0.90)
	V_2R_2	56.2 (15.0)	61.0 (18.4)	0.029	0.29	14.09 (11.26–18.84)	8.26 (6.60–11.05)	0.77 (0.57–0.88)
	V_3R_2	54.5 (16.5)	61.2 (18.1)	0.003	0.39	14.29 (11.42–19.10)	8.26 (6.60–11.05)	0.78 (0.60–0.89)
ECC	V_1R_1	105.8 (26.2)	110.8 (25.9)	0.063	0.19	9.52 (7.61–12.72)	10.31 (8.24–13.78)	0.85 (0.72–0.93)
	V_2R_1	103.1 (24.8)	110.5 (24.3)	0.019	0.30	11.12 (8.89–14.86)	11.88 (9.49–15.88)	0.78 (0.59–0.89)
	V_3R_1	108.7 (26.9)	113.1 (25.1)	0.268	0.17	13.82 (11.04–18.47)	15.33 (12.25–20.49)	0.67 (0.41–0.82)
	V_1R_2	108.3 (30.7)	112.3 (23.5)	0.189	0.14	10.53 (8.41–14.07)	11.61 (9.28–15.52)	0.83 (0.68–0.91)
	V_2R_2	107.4 (26.4)	114.2 (25.1)	0.024	0.26	10.18 (8.14–13.61)	11.28 (9.02–15.08)	0.82 (0.66–0.91)
	V_3R_2	106.9 (27.3)	117.0 (27.7)	0.010	0.37	12.90 (10.31–17.25)	14.44 (11.54–19.31)	0.74 (0.52–0.86)

ISO – isometric contraction; CON – concentric contraction; ECC – eccentric contraction; $V_0 = 0$ m·s^{-1}; $V_1 = 0.15$ m·s^{-1}; $V_2 = 0.30$ m·s^{-1}; $V_3 = 0.45$m·s^{-1}; $R_{90} = 90$ degrees; $R_1 = 25\%$ cm; $R_2 = 50\%$ cm; ES – Cohen's d effect size; CV – coefficient of variation; TE – typical error [kg]; ICC – intraclass correlation coefficient; 95% CI – 95% confidence interval.

difference between test and retest in isometric trunk extensor strength when the average or maximum strength is considered ($p > 0.05$; ES < 0.20). The ICCs varied between 0.67 and 0.85 for the average strength measurements and were between 0.55 and 0.82 for maximum strength measurements (Tables 2 and 3).

The most reliable assessment was the average in both V_1R_1 concentric and eccentric measurements concerning the manifestation of strength (Fig. 2). For isometric contraction, the most reliable strength manifestation was the maximum strength.

Finally, the strength manifestation correlating best with isometric strength was the average concentric

Table 3. Test-retest reliability of maximum strength measurements [kg] provided by the FEMD at different velocities and ranges of movements

Conditions		Day 1	Day 2	*p*-value	ES	CV (95% CI)	TE (95% CI)	ICC (95% CI)
ISO	$V_0R_{90^o}$	89.2 (21.1)	91.9 (21.3)	0.259	0.13	10.29 (8.23–13.76)	9.32 (7.45–12.46)	0.82 (0.65–0.91)
CON	V_1R_1	95.4 (20.6)	97.9 (21.4)	0.380	0.12	11.34 (9.06–15.15)	10.96 (8.76–14.65)	0.74 (0.53–0.87)
	V_2R_1	86.7 (21.8)	95.5 (20.9)	0.014	0.41	14.60 (11.66–19.51)	13.30 (10.62–17.77)	0.63 (0.36–0.80)
	V_3R_1	95.2 (27.5)	103.1 (24.0)	0.049	0.30	15.19 (12.14–20.30)	15.06 (12.04–20.13)	0.67 (0.42–0.83)
	V_1R_2	91.7 (24.2)	92.6 (18.5)	0.764	0.04	12.44 (9.94–16.63)	11.46 (9.16–15.32)	0.73 (0.51–0.86)
	V_2R_2	88.7 (21.3)	93.9 (21.3)	0.059	0.25	11.46 (9.16–15.32)	10.47 (8.37–13.99)	0.77 (0.58–0.88)
	V_3R_2	88.9 (22.1)	98.9 (23.2)	0.005	0.44	13.76 (10.99–18.39)	12.92 (10.32–17.27)	0.69 (0.45–0.84)
ECC	V_1R_1	127.9 (26.9)	132.0 (28.6)	0.211	0.15	9.63 (7.69–12.87)	12.51 (10.00–16.72)	0.81 (0.64–0.90)
	V_2R_1	130.7 (24.1)	137.1 (24.9)	0.071	0.26	10.09 (8.07–13.49)	13.51 (10.80–18.06)	0.71 (0.48–0.85)
	V_3R_1	143.0 (26.3)	146.9 (25.8)	0.388	0.15	12.17 (9.72–16.26)	17.64 (14.10–23.58)	0.55 (0.25–0.76)
	V_1R_2	134.4 (33.9)	139.1 (26.9)	0.251	0.15	11.71 (9.39–15.57)	16.02 (12.84–21.30)	0.74 (0.53–0.86)
	V_2R_2	137.7 (28.3)	141.6 (26.9)	0.189	0.17	9.66 (7.72–12.92)	13.46 (10.75–17.99)	0.77 (0.58–0.88)
	V_3R_2	142.3 (26.2)	149.1 (14.82)	0.112	0.25	11.09 (8.86–14.82)	16.16 (12.91–21.60)	0.65 (0.39–0.82)

ISO – isometric contraction, CON – concentric contraction, ECC – eccentric contraction, $V_0 = 0$ m·s^{-1}, $V_1 = 0.15$ m·s^{-1}, $V_2 = 0.30$ m·s^{-1}, $V_3 = 0.45$m·s^{-1}, $R_{90} = 90$ degrees; $R_1 = 25\%$ cm, $R_2 = 50\%$ cm, ES – Cohen's d effect size, CV – coefficient of variation, TE – typical error [kg], ICC – intraclass correlation coefficient, 95% CI – 95% confidence interval.

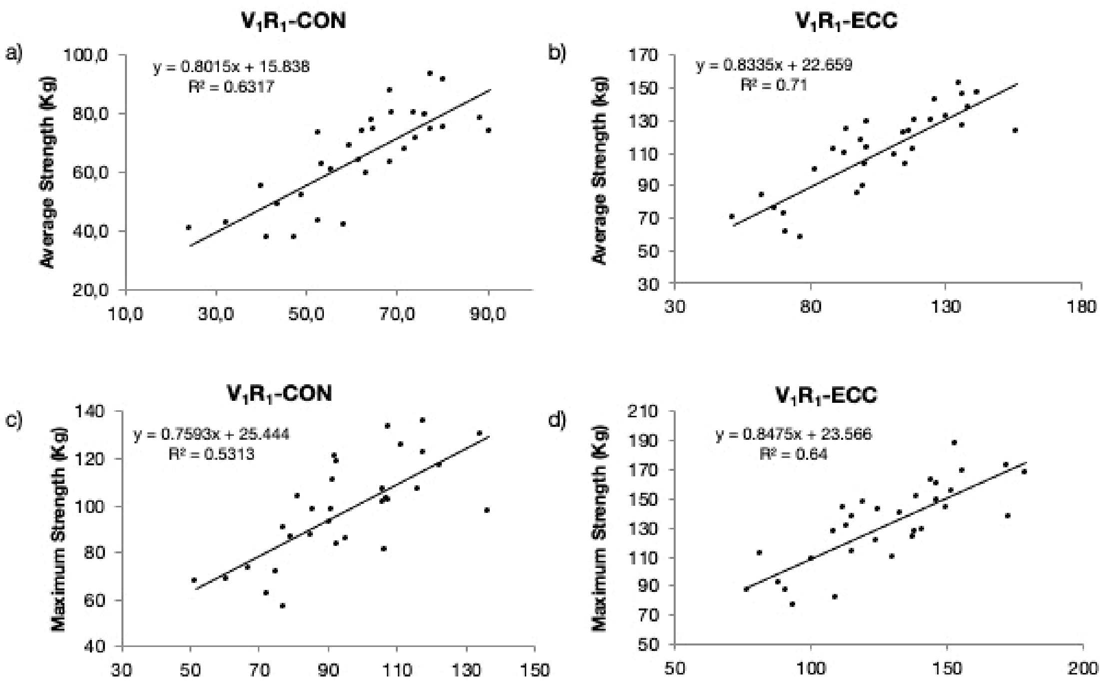

Fig. 2. Linear correlations between test and retest of concentric and eccentrics phases of average and maximum strength of trunk extensors

strength at V_2R_2 (r = 0.69) and the maximum eccentric strength of the trunk extensors at V_1R_1 (r = 0.65) (Fig. 3).

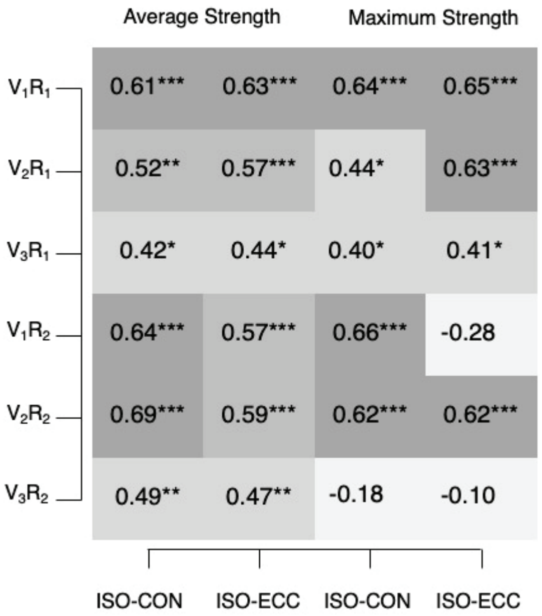

Fig. 3. Correlation coefficient (r) from Pearson correlation analysis between isometric average and maximum strength with dynamic average and maximum strength [kg]; $*p < 0.05$, $**p < 0.01$, $***\ p < 0.00$

4. Discussion

The main findings of this study were that slower velocities and shorter ranges of movement (V_1R_1) in eccentric mode have the highest absolute and relative reliability, both when considering the average strength (p = 0.063; ICC = 0.85; CV= 9.52%), as well as when considering the maximum strength (p = 0.211; ICC = 0.81; CV = 9.63%). In isometric evaluation, the most reliable strength manifestation was maximal strength (p = 0.259; ICC = 0.82; CV = 10.29%). Therefore, we can suggest that FEMD is a highly reliable tool for evaluating trunk extensors in dynamic and isometric conditions (static at 90°).

In the literature, many ranges of movement, velocities, and/or positions were considered to study the trunk extension strength measurement's reliability using isokinetic devices or hand-held dynamometers [11], [12], [44]. However, no unique protocol has been determined that provides the most excellent reliability yet. Therefore, the R and V were compared to determine which evaluation condition is more reliable in the present study. According to the results, there is evidence that the absolute and relative reliability is similar in all evaluation conditions, ranging from moderate to good reliability. Nevertheless, the greatest reliability in the concentric strength was found in short-range of movement and slower velocities (V_1R_1), considering both manifestations of strength, i.e., average (CV = 11.33%, TE = 7.23) and maximum (CV = 11.34%, TE = 10.96) strength values. The same occurs in the eccentric strength, the slower velocities, and the shortest ranges of movement (V_1R_1), are the most reliable to evaluate the trunk extensor strength when the average (CV = 9.52%; TE = 10.31) or maximum (CV = 9.63%; TE = 12.51) strength is considered. Furthermore, in this condition, there was no learning effect between the test and the retest. Therefore, the data suggest that the trunk extensors' strength should be evaluated at a velocity of 0.15 $m \cdot s^{-1}$ in a short R (25%) when using FEMD. For isometric evaluation, the most reliable values were obtained when the analyzed variable was maximum strength (CV = 10.29%, TE = 9.32) instead of the average strength (CV = 14.62%; TE = 10.77).

In most studies investigating the reliability of isokinetic trunk extensor strength, the variable commonly used as a reference is maximum strength, without previously comparing what occurs if the average strength is used [27], [40]. According to the literature, the evaluation of the isokinetic trunk muscles is performed in two main positions: seated and standing. Studies in which the extensors 'strength reliability at different V and R were evaluated in a seated position, similar values of relative reliability were obtained. Dvir et al. [12], assessing men at slow velocities and short R (20°), reported a good relative reliability (ICC = 0.78; SEM = 10.4) at 10 °/s and a moderate relative reliability (ICC = 0.62; SEM = 15.8) at 40 °/s in eccentric mode, and an ICC of 0.53 (SEM = 13.5) at 10 °/s and ICC of 0.52 (SEM = 16.4) at 40 °/s in concentric mode. In the recent study by Juan-Recio et al. [27], the authors evaluated the reliability at a higher velocity (120 °/s) and found an ICC of 0.77 for the maximum strength [27]. Using the seated position and a R of 60°, Roth et al. [40] reported a high or excellent reliability in the isometric evaluation (ICC = 0.93; CV = 6.9%) and in concentric mode an ICC of 0.92 (CV = 7.7%) at 60 °/s and an ICC of 0.85 (CV = 12.4%) at 150 °/s.

On the other hand, if we consider assessing extensor strength in the standing position, Müller et al. [34], assessing adolescents in an R of 55°, reported an ICC of 0.69 (SEM = 17.8) in isometric contraction. In concentric mode they reported an ICC of 0.94 (SEM = 7.2) evaluated at 30 °/s, an ICC = 0.83 (SEM = 12.2) at 60 °/s, and an ICC of 0.89 (SEM = 10.9) at 120 °/s. The eccentric mode only was assessed at a velocity of

30 °/s with an ICC of 0.86 (SEM = 11.9). Guilhem et al. [17] reported an excellent absolute and relative reliability when assessing the extensors muscles in isometric contraction (ICC = 0.94; SEM = 7.0), in eccentric contraction at 60 °/s (ICC = 0.94: SEM = 5.9), and in concentric contraction evaluated at 60 °/s (ICC = 0.87; SEM = 5.9) and 120 °/s (ICC = 0.88; SEM = 8.0) with a R of 60°.

Of all the values obtained in the different studies, the short-range and slow-velocity assessment performed by Dvir et al. [12] is the one that reported the lowest reliability. They attribute this to the lack of fixation of the pelvis when evaluating trunk strength in men [12]. In this study, the pelvis fixation does not seem to have influenced the measurement since the highest reliability was obtained precisely in the slowest velocity and shortest range, even though the FEMD does not have a sophisticated attachment and support system such as the classic isokinetic dynamometers. This fixation system could allow for a more natural movement. In this sense, it is interesting to consider that the isokinetic evaluation situates the subject in a condition unrelated to their natural movements. It highlights, on the one hand, the importance of a familiarization process. For example, Roth et al. [40] reported excellent reliability between test two and test five, but they found greater variation between familiarization and measurement one. And on the other hand, the need to consider settings that allow a more natural movement, as is the case of the FEMD.

It is important to note that this study's novelty was to assess which evaluation condition is most related to isometric strength. The average strength in the trunk extensors' concentric phase with the V_2R_2 condition (r = 0.69) was stronger related to the maximum isometric contraction. No previous studies analyze this in trunk extensors strength assessment, but there is a study on the trunk flexors. This study showed that the average strength of eccentric trunk flexor strength measured at high velocities but short R (r =0.73) was best related to the maximum isometric contraction [38]. Knowing which condition correlates most strongly with isometric strength can be helpful when time is limited or a patient with movement restriction needs to be assessed. A five-second isometric assessment protocol could be performed as an option.

Finally, this study is not exempt from limitations. First, we have only evaluated male students without any injuries or back pain; consequently, our data cannot be extrapolated to the rest of the population. Second, using a novel device and offering linear values of velocity and range of movement has made our research more difficult to compare with other studies. Besides, there was a learning effect with some effect sizes greater than 20% in the assessment. Similarly, just the correlation of the dynamic strength with a static condition at 90° was realized. Future research could perform the same evaluation in another type of static condition, position (standing) and population, such as patients with low back pain, people of another age range, and even female students, to further determine the best evaluation condition in these populations.

5. Conclusions

In conclusion, the FEMD is a highly reliable device to evaluate trunk extensors in dynamic and isometric condition (static at 90°). For the isometric evaluation, the maximal strength measurement was more reliable. For dynamic evaluation, the most reliable condition was in short-range and slower velocities (V_1R_1), both in concentric and eccentric contraction, and both average and maximal strength, with a large correlation with the isometric assessment.

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