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The importance of using different strength assessment variables and their relationship with handball performance

Importancia del uso de diferentes variables en la evaluación de la fuerza y su relación con el rendimiento en balonmano

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Abstract

Background: standardized general tests for physical assessment are not sensitive to provide relevant information in team sports. Functional Electromechanical Dynamometers allow the creation of specific strength assessment tasks for transfer to sport. The purposes of the study were to determine the reliability of velocity, power and work of handball specific strength tests (unilateral pullover, standing lift and step-forward), and to investigate the relationship between specific strength tests and handball performance.
Methods: fourteen elite male handball players from the first Spanish division participated in this study (28.79±4.81 years, 90.61±12.66 kg, and 1.87±0.10 m). A repeated-measurement design was used to assess handball specific strength tests and handball performance (throwing velocity (TV) and sprint time).
Results: relative reliability was very high for all the parameters (ICC≥0.7) except for velocity and power of non-dominant unilateral pullover, and for the peak velocity of non-dominant standing lift and peak and mean velocity of dominant standing lift (ICC<0.7). The TVpeak could be explained by weight, mean power and work of the dominant step-forward in the 66% and the 5m-sprint could be explained by height and mean velocity of the non-dominant step-forward in 49%.
Conclusion: these results show the importance of lower-body specific strength in handball training.
Keywords: functional electromechanical dynamometer; specific strength; team sports; athletic performance; test; reliability.

Resumen

Antecedentes: las pruebas generales estandarizadas de evaluación física no proporcionan información relevante en deportes de equipo. La Dinamometría Electromecánica Funcional permite crear tareas de evaluación de fuerza con transferencia al deporte. Los objetivos fueron determinar la fiabilidad de la velocidad, potencia y trabajo de las pruebas de balonmano (pullover unilateral, leñador y test de un paso) e investigar la relación entre las pruebas y el rendimiento en balonmano.
Métodos: se utilizó un diseño de medidas repetidas para evaluar las pruebas de fuerza específicas de balonmano y el rendimiento (velocidad de lanzamiento (VL) y sprint) en catorce jugadores de élite de balonmano (28,79±4.81 años, 90,61±12,66 kg y 1,87±0,10 m).
Resultados: la fiabilidad relativa fue muy alta para todos los parámetros (ICC≥0,7), excepto para la velocidad y la potencia del pullover unilateral no dominante, y para la velocidad pico del leñador no dominante y la velocidad pico y media del leñador dominante (ICC<0.7). La VLpico podría explicarse por el peso, potencia media y trabajo de la prueba de un paso dominante en un 66% y el sprint podría explicarse por la altura y velocidad media de la prueba de un paso no dominante en un 49%.
Conclusión: estos resultados muestran la importancia de la fuerza específica del tren inferior en el entrenamiento del balonmano.
Palabras clave: dinamómetro electromecánico funcional; fuerza específica; deportes de equipo; rendimiento atlético; prueba; fiabilidad.

Introduction

In handball, how strength is applied in court is one of the most important factors affecting player performance (Gorostiaga et al. 2004; Naisidou et al. 2017). Especially in the overhead throw action, which is key to a successful offensive phase of the game (Debanne and Laffaye 2011). High-velocity throws executed with accuracy are the most important factors for scoring a goal (Marques et al. 2007; van den Tillaar and Ettema 2004). Moreover, the shorter time required to execute a throw increases the difficulty for defenders and goalkeepers (Van Muijen et al. 1991). In this regard, to improve throwing performance, it is necessary to evaluate strength and power as indicators of high-level strength execution over short periods (Marques et al. 2007; Ortega-Becerra et al. 2018).

Another important action in handball is the short sprint ability to support technical-tactical situations, with speed and explosiveness displayed in a variety of motion planes and at adequate moment (Ferragut et al. 2018; Hermassi et al. 2017). In addition, at the elite handball level, teams with a higher efficiency of counterattacks, which require a strong development of power and speed in short-distance sprints, achieve a greater percentage of victories (Milanović, Vuleta, and Ohnjec 2018). Training to improve these movements should be applied using a close-open continuum model to manipulate the adaptations of athletes with different variables (Mota et al. 2022). Manipulation of power and speed variables can improve sprint-specific training for these situations; however, new evaluation methods must be developed.

On the one hand, the relationship between strength and throwing velocity (TV) has been tested using exercises such as bench press, meanwhile handball throws are performed with one hand in a standing position (Aguilar-Martínez et al. 2012.; Cherif et al. 2016; Ortega-Becerra et al. 2018). On the other hand, the negative association between half back squat 1-RM and repeated shuttle sprint ability (Hermassi et al. 2019) could be due to the lack of specificity of the assessment process. Nowadays, functional electromechanical dynamometers (FEMD) are a valid tool (Rodriguez-Perea et al. 2021) for the implementation of sport-specific strength tasks (Chirosa-Ríos et al. 2022; Martinez-Garcia et al. 2020; Morenas-Aguilar et al. 2024) with simultaneous assessment of strength, velocity, power and work. In fact, previous studies using FEMD have investigated strength specific tasks by analyzing mean and peak strength of handball players (Morenas-Aguilar et al. 2023, 2024). However, previous studies have not analyzed the reliability of other strength variables such as velocity, power and work and their associations with handball performance. Therefore, it would be interesting to analyze the different variables collected through the FEMD and study their relationships with handball performance parameters. Therefore, the present study aimed to determine the reliability of velocity, power and work in handball specific strength tests (unilateral pullover, standing lift and step forward) and to investigate the relationship with TV and sprint time.

Materials and Methods

A test-retest design was used to evaluate the reliability of the three handball specific strength tests in 3 sessions separated by 1 week. The design was identical to that used in a previous study, but different variables were collected for each test (velocity, power and work) (Morenas-Aguilar et al. 2024)).

Participants

Fourteen elite male handball players (28.79 ± 4.81 years, 90.61 ± 12.66 kg, and 1.87 ± 0.10 m) from the first Spanish division participated in this study. Participants were eligible for the study according to the following inclusion criteria: (1) no musculoskeletal injury during the three months preceding data collection; (2) and at least 6 years of resistance training experience. A player with a shoulder injury was excluded from the unilateral pullover and TV statistical analysis because of a shoulder injury. Furthermore, the players and coaches were informed about the nature, aims, and risks associated with the experimental procedure before giving their written consent to participate. The study protocol was conducted following the Helsinki Declaration and was approved by the Biomedical Committee of the University of Granada (nº 422/CEIH/2017).

Procedures

The subjects attended the laboratory on 3 different days. On day 1, the subjects performed a familiarization protocol for strength tests with FEMD (Dynasystem, Research Model, Granada, España) and sprint and TV were evaluated. On days 2 and 3, handball specific strength tests were evaluated with FEMD (Figure 1).

The FEMD was used to evaluate the handball specific strength tests with velocity, power and work variables. A Stalker Acceleration Testing System (ATS) II radar device (Model: Stalker ATS II, Applied Concepts, Dallas, TX, USA) and a size III handball ball (mass = 450 g; circumference = 59 cm) were used to assess TV. A photocell set (Model: DSD Laser System, León, Spain) was used to assess the sprint time. A pair of photocells was placed at starting points (0 m), 5m, 10 m, and at 20 m. The software used for data recording was SportSPEED 2.0 (DSD Laser System, León, España). All assessments were performed by two national handball coaches (Spanish National Federation, Level 3) (XXX and XXX) with 5-year experienced with FEMD devices, at the same time of day (± 1 h) for each participant and in similar environmental conditions (∼21 ◦C and ∼60% humidity).

Familiarization protocol and handball performance evaluation

The participants performed a general warm-up consisting of jogging and dynamic mobility exercises. The subjects then performed a specific warm-up and TV test, as detailed in a previous study (Aguilar-Sánchez et al. 2023). Then, a specific warm-up for the sprint test and 3 repetitions of 20-m maximal sprint were performed, taking times at 5, 10, and 20 m. Finally, the familiarization protocol with FEMD was performed similarly as described by Aguilar-Sánchez et al., 2023 (Aguilar-Sánchez et al. 2023).

Evaluation protocol with FEMD

On the second and third days, the subjects performed the same general warm-up as on the familiarization day. After that, a specific warm-up for strength tests using FEMD was completed and standing lift and unilateral pullover isometric tests were completed in a random order for each side with 3 min of rest between trials, as detailed in previous research (Morenas-Aguilar et al. 2024). An 8-second isometric repetition was performed for both the dominant and non-dominant sides, instructing participants to perform maximal effort. In incremental tests, one set of each exercise with the dominant and non-dominant sides was performed in random order. A free range of movement was allowed in the incremental test. All tests were executed until failure or were not available to maintain the technique of the exercise; thus, the range of motion of the first repetition and the correct technique in each exercise were used as guidelines. The rest time between trials was set to 3 min.

Tests for unilateral pullover and standing lift were initiated at 30% of the isometric peak force. The step forward test begins with 10% of a person's body weight. The intraserial load increment was adjusted based on the body weight range: 1kg for less than 60kg, 2kg for 60-80kg, 3kg for 81-100kg, and 4kg for more than 100kg. For unilateral pullover, one handheld the handle overhead with slight elbow flexion and the contralateral foot was positioned forward. Participants were instructed to keep their elbow forward while flexing it during the throw. For the standing lift, both hands grasped the handle of the foot with shoulder width apart and the toes pointed outward. Participants were instructed to forcefully rotate their torso and then slowly return it to its original position. For step forward, participants were instructed to step forward using the contralateral foot as fast as they could with each step and then return to the beginning in a controlled manner (Morenas-Aguilar et al. 2024).

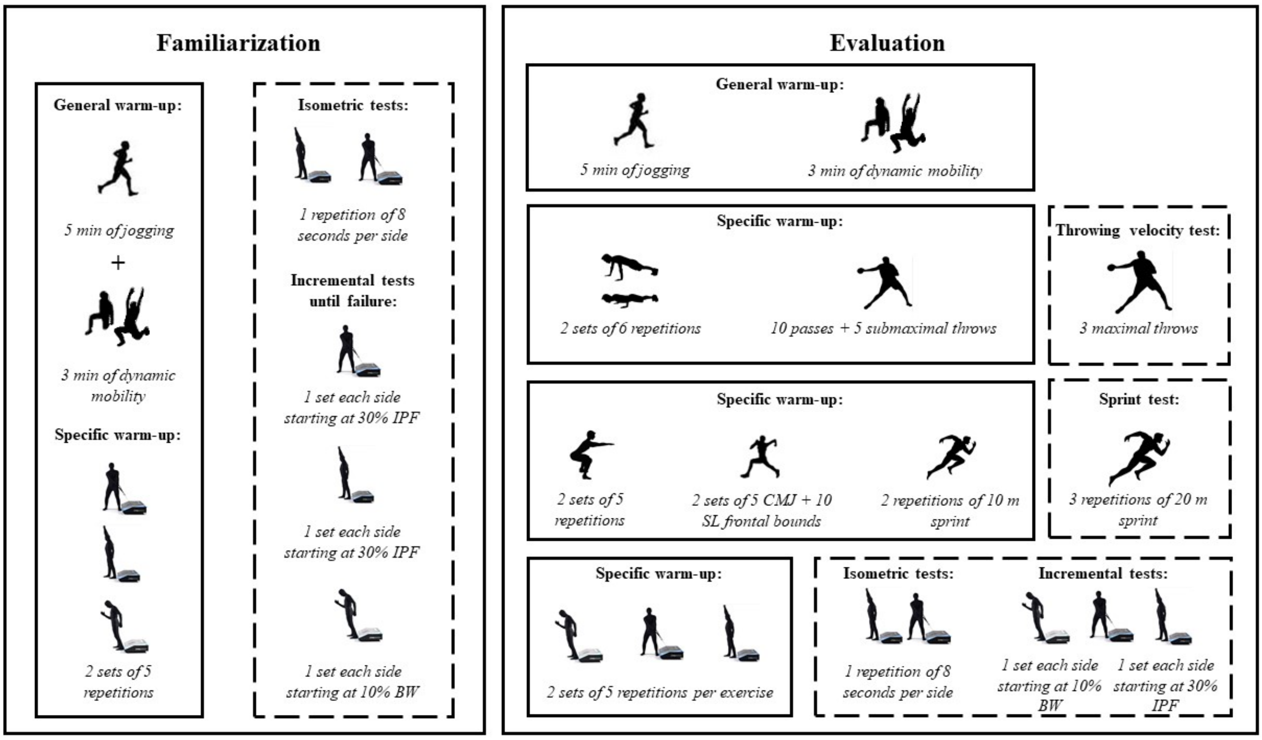

Figure 1. Project overview. Note: IPF =isometric peak force; BW =body weight; SL = single leg.

Statistical Analyses

The descriptive data are presented as mean ± SD. A Shapiro-Wilk normality test was performed for all variables ($p > 0.05$). Reliability was assessed by t-tests of paired samples with effect size (ES), coefficient of variation (CV), and intraclass correlation coefficient (ICC), with 95% confidence intervals. The scale used for interpreting the magnitude of the ES was as follows: negligible (<0.2), small (0.2–0.5), moderate (0.5–0.8), and large (≥0.8) (Cohen 1988). The following criteria were used to determine acceptable (CV ≤ 10%, ICC ≥ 0.80) and high (CV ≤ 5%, ICC ≥ 0.90) reliability. The classification through a qualitative scale of the magnitude of the values of the ICC was used, with values close to 0.1 low reliability, 0.3 moderate, 0.5 high, 0.7 very high, and those close to 0.9 extremely high (Hopkins et al. 2009). Reliability analysis was performed using a customized spreadsheet (Hopkins et al. 2009).

To develop a more precise equation for the sample, a multiple backward linear regression model was performed to assess which variable (anthropometric and FEMD measurements) best predicted the sprint and TV performance. The statistical significance for all tests was accepted at the 5% level. All statistical analyses were conducted with the statistical software package SPSS v23.0 (SPSS Inc., Chicago, IL, USA).

Results

The reliability of the velocity, power and work are presented in Table 1. Relative reliability was very high for all parameters (ICC ≥ 0.7) except for the velocity and power of non-dominant unilateral pullover, and the peak velocity of non-dominant standing lift and peak and mean velocity of dominant standing lift (ICC < 0.7).

Table 1. Reliability of velocity, power and work in the incremental testing protocol on FEMD.

		Test mean± SD	*Retest mean ± SD*	*ES(d)*	*ICC (95% CI)*	*CV (%)*	*SEM*
Velocity (cm·s^{-1})							
Unilateral pullover	Peak (D)	209.7±48.9	217.8±41.0	0.18	0.85 (0.58-0.95)	8.89	0.46
	Mean (D)	94.3±21.4	98.0±21.4	0.17	0.78 (0.43-0.93)	11.13	0.58
	Peak (ND)	209.5±28.8	228.9±31.1	0.65	0.44 (-0.12-0.79)	10.52	1.20
	Mean (ND)	103.9±18.3	109.7±23.3	0.28	0.40 (-0.17-0.77)	15.62	1.32
Standing Lift	Peak (D)	286.4±8.9	288.5±9.2	0.24	0.64 (0.18-0.87)	1.99	0.81
	Mean (D)	175.9±19.2	183.9±20.0	0.41	0.42 (-0.12-0.77)	8.54	1.26
	Peak (ND)	283.6±8.8	285.4±13.7	0.15	0.59 (0.12-0.85)	2.69	0.89
	Mean (ND)	175.4±23.4	179.6±24.4	0.18	0.85 (0.59-0.95)	5.63	0.46
Step Forward	Peak (D)	155.4±33.1	155.4±34.2	0.00	0.72 (0.32-0.90)	12.21	0.68
	Mean (D)	53.1±12.7	58.6±14.5	0.40	0.70 (0.30-0.89)	13.98	0.70
	Peak (ND)	137.8±35.6	154.2±26.7	0.52	0.83 (0.56-0.94)	9.45	0.49
	Mean (ND)	48.0±15.8	52.2±12.7	0.30	0.90 (0.71-0.97)	10.04	0.37
Power (W)							
Unilateral pullover	Peak (D)	383.4±162.8	383.7±116.3	0.00	0.88 (0.65-0.96)	14.06	0.41
	Mean (D)	135.8±43.7	138.9±30.5	0.08	0.81 (0.48-0.94)	12.97	0.54
	Peak (ND)	336.9±76.5	382.9±96.0	0.53	0.65 (0.19-0.88)	14.95	0.79
	Mean (ND)	139.4±33.9	147.3±34.3	0.23	0.63 (0.14-0.87)	15.25	0.84
Standing Lift	Peak (D)	1049.4±236.1	1056.2±263.2	0.03	0.85 (0.61-0.95)	9.75	0.45
	Mean (D)	493.6±122.3	511.1±117.1	0.15	0.83 (0.56-0.94)	10.44	0.49
	Peak (ND)	1030.9±260.3	1087.5±284.0	0.21	0.87 (0.64-0.96)	10.02	0.42
	Mean (ND)	491.8±135.7	517.9±131.1	0.20	0.90 (0.72-0.97)	9.02	0.36
Step Forward	Peak (D)	532.7±219.4	524.9±213.7	-0.04	0.87 (0.65-0.96)	15.84	0.42
	Mean (D)	144.1±38.3	156.8±42.4	0.31	0.78 (0.44-0.92)	13.53	0.58
	Peak (ND)	465.9±232.2	532.4±204.6	0.30	0.93 (0.80-0.98)	12.59	0.30
	Mean (ND)	136.4±46.8	150.8±40.6	0.33	0.89 (0.70-0.96)	10.86	0.38
Work (J)							
Unilateral pullover	Dominant	119.3±45.9	123.7±35.3	0.11	0.91 (0.73-0.97)	11.25	0.35
	Non-dominant	115.2±29.3	122.3±32.4	0.23	0.86 (0.61-0.96)	10.55	0.44
Standing Lift	Dominant	386.0±100.7	411.8±134.5	0.22	0.89 (0.69-0.96)	10.67	0.38
	Non-dominant	382.0±104.7	424.0±137.1	0.34	0.86 (0.63-0.95)	12.02	0.43
Step Forward	Dominant	179.7±47.4	195.4±47.2	0.33	0.92 (0.78-0.98)	7.53	0.31
	Non-dominant	164.5±57.4	203.9±57.1	0.69	0.87 (0.65-0.96)	11.95	0.42

D = dominant; ND = non-dominant; ES = effect size; SD = standard deviation; ICC = intraclass correlation coefficient; CV = coefficient of variation; SEM = standard error of measurement (kg); 95% CI = 95% confidence interval

Multiple backward linear regression analyses, with all TVpeak values as independent variables and weight and dominant step-forward, revealed that TVpeak could only be significantly predicted by weight and mean power and work of the dominant step-forward ($p = 0.005$). The resulting regression equation could be written as:

TVpeak = 95.51+ (-0.37 weight) + 0.11 mean power of the dominant step-forward
+ 0.09 work of the dominant step-forward
(Adjusted $R^2 = 0.66$)

Multiple backward linear regression analyses, with all 5m-sprint values as independent variables and height and mean velocity of the non-dominant step-forward, revealed that 5m-sprint could only be significantly predicted by the height and mean velocity of the non-dominant step-forward ($p = 0.01$). The resulting regression equation could be written as:

5m-sprint = 0.335 + 0.63 height + (-0.01 mean velocity of the non-dominant step-forward)
(Adjusted $R^2 = 0.49$)

Discussion

The present study was designed to determine the reliability of velocity, power and work in handball specific strength tests and to study the relationship between handball specific strength tests and performance assessed with TV and sprint time. The results provided a very high reliability for all the parameters except for the velocity and power of non-dominant unilateral pullover, peak velocity of non-dominant standing lift and peak and mean velocity of dominant standing lift (ICC < 0.7). In accordance with other studies (Chirosa-Ríos et al. 2022; Morenas-Aguilar et al. 2024), the main findings confirmed that these new tests are a reliable method of specific strength assessment through FEMD in handball players. Moreover, step-forward and anthropometric measurements (height and weight) are important for TV and 5m-sprint performance in professional handball players.

Sport evaluation is essential for the training process of every athlete, team, and coaching staff (D'Isanto et al. 2019) to improve performance. The reason for studying test reliability is to understand the test's inherent error, using the CV or SEM, to determine if the improvement was produced by training or attributable to the test's inherent error. There is currently a tendency to create evaluations similar to competition gestures (Aguilar-Sánchez et al. 2023). However, physical performance assessment in team sports used to be conducted by standardized general tests failing to provide relevant information by showing a low correlation (r < 0.5) in aerobic fitness, strength tasks, and velocity tests (Farley et al. 2020; Wagner et al. 2019). The high reliability of handball specific strength tests through FEMD with different variable, such as velocity, power and work can help to bring the evaluation closer to the reality of the game. Previous studies have assessed strength and velocity variables in specific strength movements with FEMD (Chirosa-Ríos et al. 2022; Morenas-Aguilar et al. 2023, 2024). In the present study, other variables were measured to complement the previous evaluations, highlighting the importance of the evaluation of power in the performance of team sports (Cormier et al. 2020; Loturco et al. 2018). In accordance with Chirosa-Ríos et al. 2022, velocity variables seem to have a high reliability (Chirosa-Ríos et al. 2022). Moreover, the very high reliability found in power and work variables are like strength values in the same movements of elite and young handball players (Morenas-Aguilar et al. 2023, 2024). This confirms the idea that more specific variables can be used to evaluate sports performance.

Many authors have found positive relationships between strength level and TV (Marques et al. 2007; Ortega-Becerra et al. 2018). The results showed the influence of mean power and work of the dominant step-forward alongside weight on TV. Lower and upper limb power is important to determine TV (Bøgild, Jensen, and Kvorning 2020; Chelly, Hermassi, and Shephard 2010; Wagner et al. 2014), especially the capacity of the upper-body to move low loads at maximal velocities and the peak power of the lower extremities (Ortega-Becerra et al. 2018). Therefore, isoinertial resistance training and ballistic training show greater TV improvements than traditional training (Bouagina et al. 2022; Madruga-Parera et al. 2021). In addition, Aguilar-Sánchez et al. (2023) also found a positive correlation between mean strength step-forward and TV in elite handball players (Aguilar-Sánchez et al. 2023). In contrast, mean strength of standing lift and arm span was the most influential variable among young handball players (Morenas-Aguilar et al. 2023). The discrepancies between the results could be explained due to the age difference (28.8 ± 4.8 years vs. 15.14 ± 0.38 years). Elite handball players with years of strength and specific handball training experience are capable of efficiently transferring strength from the lower body to upper body movements (Gutiérrez Dávila et al. 2011).

Meanwhile, short high-intensity efforts, specifically short distance sprints, are important actions in handball competitions (Luteberget and Spencer 2017; Michalsik, Madsen, and Aagaard 2014), and the association between sprint time and strength is more unstable. In line with the present results, elite players with more training experience were found to be significantly faster over 5- and 15-m sprint running (Granados et al. 2007). However, other studies have indicated that sprint velocity does not improve after strength training (Hermassi et al. 2017). Hermassi et al. (2019) showed that the strongest players in 1-RM half squats were the worst in sprint but had a higher performance in jumping (Hermassi et al. 2019). This could be due to the importance of horizontal force application in 10-20m sprint and the importance of acceleration capability in short sprints (Morin and Sève 2011; Simperingham, Cronin, and Ross 2016).

Handball alongside other team sports should focus on training acceleration capacity (Simperingham et al. 2016) with similar lower body movements and high-power development as step-forward to improve performance in short duration actions. Despite this, core strength measured with standing lift has a greater influence on young handball players sprint performance (Morenas-Aguilar et al. 2023). These differences could be explained by the lower intramuscular and intermuscular coordination observed in children (Dotan et al. 2012).

The main limitation of this present study was the small sample (n = 14). Although the group tested was from an elite level with great homogeneity in their characteristics and training regime, it was very difficult to evaluate such players because of their competitive demands. Furthermore, only male players participated, so the results could not be extrapolated to females. However, it is important to highlight the importance of reliability in an effective incremental test for time used and the accumulated fatigue, based on maximal isometric strength and body weight. In addition, the use of new technologies allows us to perform maximal tests efficiently and set test values.

Conclusions

The specific FEMD tests proposed (unilateral pullover, standing lift and step forward) are reliable methods to be included in the assessment process and specific training programs for handball players. Moreover, step-forward is important for predicting TV and 5m-sprint alongside anthropometric measurements (height and weight) in professional handball players.

Practical Applications

The results of this study will provide a significant contribution to strength and conditioning coaches when preparing training programs. To improve training and competition, it is necessary to evaluate progress. The FEMD provides an opportunity to make efficient, individual and similar evaluations of sporting gesture. The specific FEMD tests proposed (unilateral pullover, standing lift and step forward) are a reliable method to be included in the assessment process and specific training programs of handball players. Moreover, step-forward is important for predicting TV and 5m-sprint along with anthropometric measurements (height and weight) in professional handball players. Therefore, strength and conditioning coaches are recommended to include this exercise either using resistance bands or weighted implements in their training routines.

Author Contributions: María Dolores Morenas-Aguilar contributed with data collection, manuscript writing and revised the manuscript critically. Angela Rodríguez-Perea and Luis Javier Chirosa-Rios lead the proyect, the methodology design, data analysis and revised the manuscript critically. Javier Aguilar-Sánchez contributed with manuscript writing and revised the manuscript critically. All authors contributed equally to the manuscript and read and approved the final version of the manuscript.

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