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Lack of experience in the use the rotational inertia device is a limitation to mechanical squat performance

La falta de experiencia es una limitación para el rendimiento mecánico en sentadillas cuando se usan dispositivos de inercia rotacional

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Abstract. It has been showed that previous experience in the use of rotational inertia devices (RIDs) enhances acute performance outcomes. The purpose of this study was to examine the differences in kinetic and kinematic profiles between athletes with and without experience in the use of different RIDs. Thirty-nine healthy men performed a half-squat incremental test on two different RIDs: a horizontal cylinder (YY) and a vertical cone-shaped axis (CP). The participants were grouped based on experience in the use of rotational inertia devices. Time, peak velocity, peak force, time to reach peak force, average force, impulse, and range of movement were analyzed to determine the differences between groups. Several biomechanical parameters differed between experts and non-experts using the same device with the same moments of inertia. Range of movement was higher in expert than in non-expert subjects only in YY devices. Experts achieved higher values using CP and YY devices in squat exercises than non-experts, except for eccentric peak force for YY. Previous experience in the use of RIDs will influence the results obtained in squat exercises.
Key words: Strength training, flywheel paradigm, impulse, force-velocity, eccentric-overload.

Resumen. Se ha mostrado que la experiencia previa en el uso de dispositivos de inerciales rotatorios (RIDs) aumenta la respuesta del rendimiento de forma aguda. El objetivo de este estudio fue examinar las diferencias en perfiles cinéticos y cinemáticos entre atletas con o sin experiencias en el uso de diferentes RIDs. Treinta y nueve hombres sanos realizaron un test incremental en el ejercicio de media sentadilla en dos RIDs diferentes: un dispositivo de eje horizontal con forma cilíndrica (YY) y otro de eje vertical y forma cónica (CP). Los participantes se agruparon en función de la experiencia en el uso de los dispositivos de inercia rotacional. Se analizaron el tiempo, la velocidad pico, la fuerza pico, el tiempo para alcanzar la fuerza pico, la fuerza promedio, el impulso y el rango de movimiento con el objetivo de determinar diferencias entre los grupos. Varios parámetros biomecánicos difirieron entre expertos y no expertos al usar el mismo dispositivo con los mismos momentos de inercia. El rango de movimiento fue mayor en los sujetos expertos que en los no expertos solo en los dispositivos YY. Los expertos lograron valores más altos usando dispositivos CP y YY en ejercicios de sentadilla que los no expertos, excepto en la fuerza pico excéntrica para YY. La experiencia previa en el uso de RIDs influirá en los resultados obtenidos en los ejercicios de sentadilla.
Palabras Clave: Entrenamiento de fuerza, paradigma flywheel, impulso, fuerza-velocidad, sobrecarga excéntrica.

Introduction

Rotational inertia devices (RIDs) have been designed to use the moment of inertia of a rotating flywheel to provide a maximal resistance overload during concentric (CON) and eccentric (ECC) phases of movement (Nunez Sanchez & Saez de Villarreal, 2017). Recently, there has been increasing interest in the use of these devices to improve human performance (de Hoyo, de la Torre, et al., 2015; Norrbrand, Fluckey, Pozzo, & Tesch, 2008; Norrbrand, Pozzo, & Tesch, 2010; Nunez, Suarez-Arrones, Cater, & Mendez-Villanueva, 2017; Sabido, Hernandez-Davo, Botella, Navarro, & Tous-Fajardo, 2017; Tesch, Ekberg, Lindquist, & Trieschmann, 2004). One of the main reasons for using this technology for training is that the ECC force has shown significantly higher values compared to free-weights (Nunez et al., 2017). These systems provide a source of linear resistance from a tether wrapped around a horizontal cylinder-shaped (YY) (Norrbrand et al., 2008) or a vertical cone-shaped shaft (CP) (Maroto-Izquierdo, Garcia-Lopez, & de Paz, 2017; Nunez et al., 2017). The kinetic energy from the CON phase of the exercise is transferred to the ECC phase, where an equal impulse is necessary to halt the rotation of the moment of inertia (Nunez et al., 2017). To be efficient using an RID, the athlete tends to apply force at maximal velocity during the CON, and halt the rotation during the ECC to produce force enhancement in the subsequent CON phase (Nunez Sanchez & Saez de Villarreal, 2017).

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Fine-tuning the strategy for optimizing the CON-ECC force in RIDs appears to require some previous experience (Tous-Fajardo, Maldonado, Quintana, Pozzo, & Tesch, 2006). Berg and Tesch (Berg & Tesch, 1994) indicated that by allowing for a short pause immediately after completion of the concentric action, a sudden steep rise in force will occur while attempting to stop the movement at the end of the ECC phase, and produce eccentric overload (EO). Increases in muscle force were noted through the use of these devices to produce EO during short periods of training (de Hoyo, Pozzo, et al., 2015; Norrbrand et al., 2008; Norrbrand et al., 2010; Tesch et al., 2004), and these improvements were higher than those with traditional methodologies (Norrbrand et al., 2008; Norrbrand et al., 2010). Tous-Fajardo et al. (Tous-Fajardo et al., 2006), using a horizontal cylinder-shaped device in a open kinetic chain exercise (i.e., YY leg curl), found that athletes who had previous experience using this technology showed greater eccentric and concentric peak forces than athletes who never used such devices. In this research, Tous-Fajardo et al. (Tous-Fajardo et al., 2006) showed that the strategy of applying force in the CON phase of the movement was similar regardless of the participants' experience, but the peak eccentric force occurred later in the range of motion in the experienced (Exp) than in the non-experienced (Non_exp) group. These authors argue that, using a YY leg curl, the Non_exp group, because of involuntary self-protection mechanisms, avoided high peak forces in the final part of the eccentric action, so a certain amount of coordination is needed to apply maximal force during the CON-ECC phases of the movement. However, previous studies have used different RIDs without controlling the participants' experience or the EO magnitude (de Hoyo, Pozzo, et al., 2015; Martinez-Aranda & Fernandez-Gonzalo, 2017; Sabido, Hernandez-Davo, & Pereyra-Gerber, 2018). A recent study observed that the vertical or horizontal shaft orientation influences the magnitude of the eccentric peak force despite using the same moment of inertia in both devices (Nunez, Galiano, Munoz-Lopez, & Floria, 2020). In order to understand the effects of flywheel training, it is necessary to know to what degree experience and the type of device used influence biomechanical output, since lack of experience could be a limitation when trying to increase performance with these devices in inexperienced subjects Consequently, the purpose of this study was to examine the differences in kinetic and kinematic profiles between athletes with and without experience in the use of RIDs. It was hypothesized that the kinetic and kinematic variable outputs in YY and CP inertial devices are dependent on the experience of the athlete with this technology, especially in the ECC phase of the movement, so performance will be greater for experienced athletes.

Material and Methods

Participants

Thirty-nine healthy, active men were recruited to participate in this study. Twenty two of these men (mean ± SD; age: 23.1 ± 4 years, height: 1.75 ± 0.69 m, and weight: 74.8 ± 11 kg) had previous experience (> 1 year, twice a week) using RIDs (Exp), and 17 with similar physical characteristics (mean ± SD; age: 22.7 ± 2.9 years, height: 176.1 ± 5.9 cm, and weight: 72.9 ± 9.8 kg) had only experienced 1 or 2 familiarization sessions (Non_exp). The study was approved by the Virgen Macarena y Virgen del Rocio University Hospitals ethics committee (0398-N-17) and was conducted in accordance with the Declaration of Helsinki. After a detailed explanation of the aims, benefits, and risks involved in this investigation, all participants gave written informed consent.

Procedure

The experimental procedure consisted of the assessment of force and velocity during a half-squat incremental test performed on a conical inertial device (CP; Costa Mesa, CA, USA) with diameters of the base and vertex of .1 m and .03 m respectively, and on a cylinder inertial device (YY; YoYo™ Technology AB, Stockholm, Sweden) with a diameter of .02 m for both experienced (Exp) and non-experienced (Non_exp) participants (see Figure 1). After a 7- to 8-min standardized general warm-up, including jogging, joint mobility exercises and two sub-maximal sets of 7 reps of a half-squat exercise in each RID, three sets of seven maximal repetitions with three different moments of inertia were performed on the CP (CPi0.11, CPi0.22 and CPi0.33 kg/m2) and on the YY (YYi0.11, YYi0.22, YYi0.33 kg/m2), with three min of recovery between sets. The exercise required the participants to wear a harness fastened at both shoulders and waist. To offer the same resistance to movement in both systems, the same numbers of pulleys were used, except in the CP, which because of its arrangement needed an extra pulley to move the participant away from the .40 m array. The execution of the squat was identical in both systems (see Figure 1). The tension of the tether was adjusted while maintaining both legs in extension. The movement was initiated by winding the tether until reaching 90° of knee flexion. The participant used two repetitions to increase the velocity. Thereafter participants were requested to apply force throughout the course of the full upward movement at maximal velocity and then resist during the final downward movement, aiming to bring the device to a stop at a ~90º knee angle before initiating the next cycle (Fernandez-Gonzalo, Lundberg, Alvarez-Alvarez, & de Paz, 2014). The tests were performed on two different days with a minimum separation of 72 h, and the order of the tests was randomized for each subject.

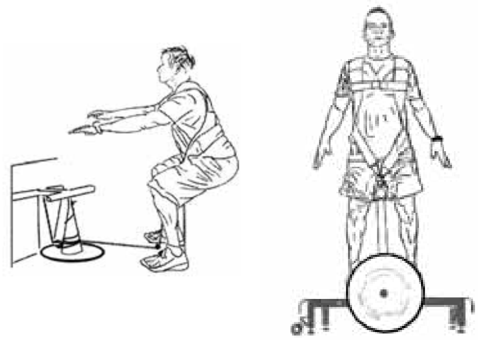

Figure 1. Half squat with CP (A) and with YY (B)

Vertical ground reaction force data were record using two force platforms (SmartCoach Europe AB, Stockholm, Sweden), with the participant standing with one leg on each platform. Vertical velocity was measured with a linear encoder (Smartcoach Power Encoder, SmartCoach Europe AB, Stockholm, Sweden) attached to the harness worn by the participant. Vertical velocity and vertical force data were sampled at 100 Hz and synchronized using an analog-to-digital converter (SmartCoach Europe AB, Stockholm, Sweden). The vertical displacement was derived by integrating the vertical velocity.

All calculations were carried out in Matlab (MatlabWorks Inc., Natic, MA, USA). A maximal repetition was defined as the event between the participant's crouch position and the participant returning to the starting position. Subsequently each maximal repetition was split into two phases: CON (upward movement) and ECC (downward movement). Time (s), peak velocity (m·s^-1), peak force (N), time to reach peak force (I: % of Time from the beginning of the phase), average force (N) and impulse (N·s) were assessed in both the concentric and eccentric phases. The impulse was calculated as the area under the force versus time curve. The range of movement (ROM) (m) was measured using the difference between minimum and maximum vertical position from the displacement records.

Statistical analyses

Data are presented as mean ± standard deviation (SD). The normality of the distribution of the data was verified using the Shapiro-Wilk test. To compare all the variables between Exp and Non-exp an unpaired t-test with a significance level of $p < .05$ and standardized differences (± 90% CI) were used. The effect size (ES, 90% confidence limit (CL)) of the selected variables was calculated using the pooled pre-training SD. The threshold values for the Cohen ES statistics were >.2 (small), >.6 (moderate), and >1.2 (large) (Hopkins, Marshall, Batterham, & Hanin, 2009). For qualitative assessment, the chance that any difference was better/greater (e.g., greater than the smallest worthwhile change, SWC [.2 multiplied by the between-subject SD based on Cohen's d principle, ES]), similar or worse/smaller than that of the other group was subsequently calculated. The quantitative chances of beneficial/better or detrimental/poorer effects were assessed qualitatively as follows (Batterham & Hopkins, 2006; Hopkins et al., 2009) : <1%, most likely not; >1-5%, very unlikely; >5-25%, unlikely; >25-75, possible; >75–95%, likely; >95–99%, very likely; and >99%, most likely. If the chance that the true value was >0.5% harmful, the non-clinical effect was considered as unclear (Hopkins et al., 2009).

Results

The results of the between-group analyses are shown in Table 1. The Exp group showed a significantly higher ROM than the Non-exp group in all YY moments of inertia (%: +7.8-8.4; ES: .48-.60). The exercise lasted significantly more time for Non-exp in all CP moments of inertia during the CON phase (%: +6.9-13.7; ES: .5-1.12) and ECC phase (%: +7.2-15.6; ES: .46-.83). During both device and all moment of inertia tests, Exp showed significantly higher peak_velocity_CON (%: +8.9-14.4; ES: .57-.80) and peak_velocity_ECC (%: +9.2-18.8; ES: .57-.80). Non_exp I_CON was significantly higher than that of the Exp in both devices and for all moments of inertia (%: +16.1-37.3; ES: .22-.35) except for YYi0.33. Nevertheless, Exp I_ECC was significantly higher than that of Non_exp in both devices and for all moment of inertia tests (%: +25.8-45.2: ES: .41-1.82).

Table 1.
A comparison of time, peak velocity, peak force, I, average force, impulse, and range of movement (mm) between Exp (n=22) and Non_ Exp (17). Data are Mean ± SD.

		CPi0.11	CPi0.22	CPi0.33	YYi0.11	YYi0.22	YYi0.33
range of movement (m)	Exp	0.35 ± 0.05	0.38 ± 0.05	0.39 ± 0.05	0.38 ± 0.07 ^{**ML}	0.37 ± 0.05 ^{**ML}	0.35 ± 0.05 ^{**ML}
	Non_Exp	0.35 ± 0.06	0.37 ± 0,05	0.38 ± 0.06	0.35 ± 0.05	0.34 ± 0.06	0.33 ± 0.06
time_CON (s)	Exp	0.67 ± 0.08	0.76 ± 0.08	0.86 ± 0.11	1.05 ± 0.19	1.30 ± 0.25	1.50 ± 0.23
	Non_Exp	0.76 ± 0.13 ^{**ML}	0.82 ± 0.14 ^{**ML}	0.92 ± 0.15 ^{**ML}	1.02 ± 0.17	1.28 ± 0.19	1.48 ± 0.21
time_ECC(s)	Exp	0.68 ± 0.13	0.72 ± 0.09	0.82 ± 0.13	1.04 ± 0.19	1.30 ± 0.23	1.56 ± 0.28
	Non_Exp	0.80 ± 0.22 ^{*ML}	0.82 ± 0.18 ^{**ML}	0.89 ± 0.17 ^{**ML}	1.00 ± 0.18	1.28 ± 0.23	1.59 ± 0.33
Peak_velocity_CON (m·s^-1)	Exp	0.92 ± 0.16 ^{**ML}	0.88 ± 0.13 ^{**ML}	0.79 ± 0.12 ^{**ML}	0.57 ± 0.09 ^{**ML}	0.44 ± 0.06 ^{**ML}	0.35 ± 0.05 ^{**ML}
	Non_Exp	0.79 ± 0.15	0.77 ± 0.10	0.71 ± 0.09	0.51 ± 0.05	0.39 ± 0.04	0.33 ± 0.04
Peak_velocity_ECC (m·s^-1)	Exp	0.87 ± 0.16 ^{**ML}	0.86 ± 0.13 ^{*ML}	0.77 ± 0.11 ^{**ML}	0.57 ± 0.10 ^{**ML}	0.46 ± 0.08 ^{**ML}	0.37 ± 0.06 ^{**ML}
	Non_Exp	0.71 ± 0.16	0.72 ± 0.14	0.69 ± 0.12	0.51 ± 0.07	0.39 ± 0.04	0.33 ± 0.07
I_CON (%)	Exp	54.53 ± 28.51	57.19 ± 24.76	53.79 ± 27.29	43.98 ± 27.97	50.18 ± 24.17	59.04 ± 20.68
	Non_Exp	62.04 ± 29.26 ^{**VL}	59.85 ± 28.10 ^{**VL}	63.95 ± 30.96 ^{**VL}	58.38 ± 31.57 ^{*ML}	61.33 ± 27.13 ^{*VL}	61.72 ± 24.02
I_ECC (%)	Exp	49.26 ± 9.90 ^{*ML}	57.03 ± 8.43 ^{**ML}	59.13 ± 8.67 ^{*ML}	58.87 ± 20.87 ^{**ML}	58.10 ± 18.84 ^{**ML}	54.31 ± 18.07 ^{**VL}
	Non_Exp	38.49 ± 18.91	47.52 ± 19.32	53.13 ± 17.59	47.06 ± 27.60	49.78 ± 24.17	48.12 ± 24.45
peak_force_CON (N)	Exp	2290.7 ± 426.9 ^{**ML}	2376.3 ± 349.6 ^{**ML}	2398.8 ± 369.4 ^{**ML}	2453.0 ± 426.2 ^{*ML}	2516.2 ± 465.4 ^{*ML}	2508.0 ± 513.5 ^{**VL}
	Non_Exp	1950.2 ± 382.2	2.093.8 ± 388.6	2173.9 ± 376.3	2252.6 ± 378.2	2333.9 ± 369.3	2367.2 ± 363.3
peak_force_ECC (N)	Exp	2000.5 ± 434.4 ^{*ML}	2.035.3 ± 378.5 ^{**ML}	2038.7 ± 377.6 ^{**ML}	2337.1 ± 467.5 ^{**VL}	2371.0 ± 476,5	2382.6 ± 565.2
	Non_Exp	1784.9 ± 372.6	1.878.8 ± 353.0	1885.2 ± 362.6	2239.6 ± 416.1	2284.2 ± 404.6	2342.8 ± 444.2
mean_force_CON (N)	Exp	1601.1 ± 262.1 ^{**ML}	1.702.7 ± 257.1 ^{**ML}	1763.3 ± 271.1 ^{**ML}	1835.5 ± 321.8 ^{*ML}	1919.1 ± 364.6 ^{*ML}	1915.4 ± 379.3 ^{**VL}
	Non_Exp	1361.7 ± 238,9	1.532.5 ± 274.2	1608.8 ± 274.6	1703.8 ± 278.9	1794.9 ± 293.6	1815.2 ± 272.6
mean_force_ECC (N)	Exp	1.340.4 ± 223.6 ^{*ML}	1.430.2 ± 238.1 ^{**ML}	1460.9 ± 258.8 ^{**ML}	1693.9 ± 344.0 ^{*VL}	1786.5 ± 363.7 ^{*VL}	1802.2 ± 399.6 ^{*VL}
	Non_Exp	1180.8 ± 248.1	1.301.3 ± 256.5	1362.8 ± 255.7	1599.6 ± 286.1	1701.9 ± 297.3	1711.3 ± 333.9
impulse_CON (N·s)	Exp	1044.1 ± 118.1 ^{*VL}	1.273.7 ± 118.0 ^{**ML}	1479.9 ± 132.9 ^{*VL}	1861.2 ± 198.5 ^{**ML}	2403.8 ± 267.7 ^{**ML}	2798.7 ± 332.5 ^{**ML}
	Non_Exp	1010,3 ± 142.7	1.218.1 ± 126.6	1435.4 ± 166.5	1694.1 ± 172.8	2227.5 ± 176.6	2636.6 ± 251.9
impulse_ECC (N·s)	Exp	896.1 ± 128.6	1.026.9 ± 134.9	1183.8 ± 143.6	1714.9 ± 221.4 ^{*ML}	2247.5 ± 207.8 ^{**ML}	2728.0 ± 280.9 ^{**ML}
	Non_Exp	907.9 ± 155.9	1.029.4 ± 121.9	1179.1 ± 135.3	1570.7 ± 210.6	2128.9 ± 229.4	2645.7 ± 322.5

Note: * Significant differences between groups ($p< .05$); ** Significant differences between groups ($p< .01$); ^{VL} Very likely substantial differences between groups; ^{ML} Most likely substantial differences between groups. Exp: group with experience in RIDs, Non_Exp: group without experience in RIDs, I_ECC: time to reach peak force for the eccentric action, I_CON: time to reach peak force for the concentric action.

The Exp group showed a significantly higher peak_force than Non-exp in both devices and all moments of inertia during the CON phase (%: +6.7-15.1: ES: .22-.93) and in both devices and all moments of inertia during the ECC phase (%: +7.7-10.8; ES: .21-.57) except for YYi0.22 and YYi0.33. Exp had a significantly higher mean_force than Non-exp in both devices and all moments of inertia during both CON (%: +6.1-15.2; ES: .23-1.03) and ECC (%: +6.9-12.6; ES: .21-.81) phases. Exp impulse_CON was significantly higher than that of Non_exp in both devices and for all moments of inertia (%: +3.3-8.9; ES: .33-.88). However, the impulse_ECC was significantly higher in Exp than in Non_exp only for YY inertias (%: +3.6-8.51; ES: .37-.70).

Discussion

The purpose of this study was to examine the differences in kinetic and kinematic profiles between athletes with and without experience in the use of RIDs. The main findings of this study were: a) the kinematics differed between Exp and Non_exp groups using the same device with the same moments of inertia; b) the ROM was higher in Exp than in Non_exp subjects only inYY devices; c) Exp achieved higher performance using both CP and YY devices, in the squat exercise, than Non_exp, except for eccentric peak_force with YY.

The exercise lasted significantly longer for Non_exp using a CP device in both CON and ECC phases. Using a YY device, both groups showed the same CON-ECC time, but the range of movement was significantly higher in Exp than in Non_exp for all YY moments of inertia. Although participants were requested to delay the braking action in the eccentric phase, our results showed that the peak_force during the ECC phase was delayed with respect to the start of the next CON phase of the movement significantly more in Non_exp (410-820 ms) than in Exp (340-700 ms). This agrees with Tous-Fajardo et al. (Tous-Fajardo et al., 2006), who found that a certain amount of coordination is needed to apply maximal force during the end of the ECC phases of movement (in this case a closed kinetic chain exercise), but it does not appear that any involuntary self-protection mechanism for avoiding high peak forces applied in the final part of the eccentric action, since both groups showed similar ECC peak_force at higher YY moments of inertia. Our subjects had more previous experience (> 1 year) than the subjects in Tous-Fajardo et al.'s study (5 sessions), so a possible explanation for the results is that the response of expert subjects, chronically sustaining high eccentric moments of inertia in a closed kinetic chain exercise, is to increase their ROM, as occurred in our study for the YY device. This fact is in line with the idea that lengthening the range over which a force is applied improves movement performance as long as the applied force levels are maintained (Floria, Gomez-Landero, Suarez-Arrones, & Harrison, 2016; McBride, Kirby, Haines, & Skinner, 2010; McBride, Triplett-McBride, Davie, & Newton, 1999). Taken together, these results suggest the need to monitor the range of motion while using RIDs in order to assess performance. Another possible explanation for these differences could be that in our study we used a closed kinetic chain exercise (i.e., half squat), and Tous-Fajardo et al. (Tous-Fajardo et al., 2006) used an open kinetic chain (i.e. leg curl) where stopping the movement at the end of the ECC phase appears be easier (Nunez et al., 2020). Further research comparing the kinetic (force) and kinematic (velocity) curves of closed kinetic chains vs. closed kinetic chains with the same moments of inertia is needed.

This study proposed the use of the impulse variable as a load measurement that allowed us to compare records between different RIDs and between different inertias for each device. Exp achieved a significantly higher impulse than Non_exp during the CON phase of the movement with both CP and YY devices. However, during the ECC phase Exp only obtained a significantly higher impulse than Non_exp with YY devices. A possible explanation for these differences could be that a YY device offers more resistance to decelerating the movement compared to a CP (Nunez et al., 2020), allowing greater discrimination between Exp and Non_exp. In fact, Exp showed higher peak_velocity and mean_force than Non_exp in the CON and ECC phases of movement with both YY and CP devices. Equally, Exp showed higher peak_force than Non_exp in the CON phase of movement with YY and CP devices, but during the ECC phase only displayed significant differences with CP and YYi0.11. It is possible that the existence of a similar range of movement for both groups in CP moments of inertia and a significantly greater range in Exp than in Non_exp for YY moments of inertia could have influenced the results for peak_force_ECC. Further research comparing the kinetic (force) and kinematic (velocity) curves of different RIDs with the same moments of inertia as training intensity in Exp and Non_exp is needed. We found no similar studies in the literature with which we could compare our results. The only study located was by Moras et al. (Moras & Vazquez-Guerrero, 2015), in which a half squat exercise was performed with a CP (.27 kg/m2), and limiting movement to the area with the smallest cone diameter obtained an average_force (CON: 1602 N; ECC: 1400 N) similar to those obtained in our study for the Exp group, and a little higher than those obtained for the Non_exp group.

This work has a possible limitation that should be acknowledged. We used a linear encoder for the description of the up and down movement, and this does not determine all of the movement of the centre of mass; only the movement that occurs where the encoder is anchored, which in this case was the harness. Given this limitation, this procedure is widely used in sports for the analysis of linear up and down movements such as squats in order to determine the phases in which a subject is moving up or down (Moras & Vazquez-Guerrero, 2015).

Conclusions

A certain amount of coordination is needed to fully benefit from a RID training (Tous-Fajardo et al., 2006), so previous experience in the use of these systems will influence the results obtained, specially if it involves exercises in a closed kinetic chain where the displacement is done against the force of gravity, as in our study. In summary, this study demonstrated differences in biomechanical output between athletes with different levels of experience in the use of RIDs. These differences were consistent in the two systems analyzed. These results provide very important information for physical trainers or researchers who use RIDs to improve strength performance.

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