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Neuromuscular and Functional Responses Among Males Trained with Free Weights vs. Machines: Implications for Injury Prevention

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ABSTRACT

The purpose of this study was to compare balance, functional performance and isometric hip strength muscle among males practitioners of resistance training (RT) with Free-weights and Machines. Thirty males were recruited and separated into two groups: Free-weights (n = 15) and Machines (n = 15). Free-weights group showed a routine of RE that engaged the whole body with resistance bands, free-weights, dumbbells, and medicine balls. Conversely, machine group trained only exercises on machines. All participants underwent three tests to assess balance, functionality, and isometric muscle strength. All tests were performed in a single assessment session in the following order: Y Balance test; functional performance testing; and maximal isometric hip strength, respectively. The two-way ANOVA yielded main effects for group in the anterior ($F_{1,22}$= 12.11, p<.002), posteromedial ($F_{1,22}$= 16.87, p<.0005), posterolateral ($F_{1,22}$= 15.97, p<.0006) and composite ($F_{1,22}$= 21.39, p<.0001) in performance during YBT between free-weight vs. machines group for both legs. Single leg step down (SLSD) and Single leg hop (SLH) test demonstrating better functional performance in the free-weight group for both legs (p<.001). Isometric muscle strength of hip abduction and extension showed lower in the machines when compared to free-weight group for both legs. This study showed greater balance, functional performance and isometric muscle strength of hip abduction and extension in males trained with Free-weight. Males trained with machines showed lower functional performance, balance and lower muscle strength of hip abductors and extensors strength and risk of injuries.

Keywords: resistance training, balance, functional performance, isometric muscle strength.

INTRODUCTION

Resistance training (RT) is a systematic physical activity modality with the objective of increase muscle strength to overcome resistance.[1,2] Thus, RT have been suggested in sports guidelines aiming at improving physical conditioning, health and injury prevention.[3,4] The RT represent a combination of dynamic actions and static effort, associated with variables that must be considered, such as: exercise order, rest interval between sets, exercise mode, training frequency, movement velocity, training volume, repetitions per set, number of sets and the load intensity.[1-4] However, some models of

RT offer a framework for planned and systematic variation of training parameters, in a way that directs biomechanics and physiological adaptations to the training goals. Specifically, there are differences of opinion whether the use of a RT program that consist of free-weights or machines is better for building muscle mass, strength, functional performance and injury prevention.[5-7]

Free-weights utilize isotonic resistance that requires to muscles a concentric contraction of the agonist while simultaneously displaying eccentric of the antagonist (or vice versa), causing a significant change to the length of the muscle and resistance throughout the range of motion; thus, free-weights allow for movement in multiple planes requiring balance by the executioner himself. 5-8 Therefore, free-weights exercises are more versatile which can be made a variety of exercises with a simple set of dumbbells, barbells, kettlebells, etc. However, the machines are training devices that have pin loaded weight stacks being carried out in a fixed form that is limited to moving through fewer planes with a stable environment.[5-8] Thus, RT with machines provide a safer use than free weights and can be used relatively easy without supervision under any circumstances. But, interestingly, regarding balance, functional performance and isometric hip strength muscle there are a limited number of studies that comparing RT with free-weights versus machines.

Neuromuscular and functional assessment has allowed a better understanding of the physiological, biomechanics responses and injury prevention associated to modes of training. Hence, measurement of balance, functionality and muscle strength are crucial for providing information regarding the muscular condition in addition to functional capacity.[9-11] These neuromuscular and functional responses are important to understand the relationship of morphological and neural factors including muscle cross-sectional area and architecture, musculotendinous stiffness, motor unit recruitment, rate coding, motor unit synchronization, balance and neuromuscular inhibition.[6-13] Such combinations of factors are associated with enhanced external mechanical power, general skill performance, and decreased injury rates.[2-11] However, it is important to point out that little is known about the effect of the RT with Free- Weights versus Machines in neuromuscular and functional performance. The absence of data supports the need for additional studies in this area. Hence, the purpose of this study was to compare balance, functional performance and isometric hip strength muscle among males practitioners of RT with Free-weights and Machines. We hypothesized that subjects trained with Free-Weights would show a better performance among all the investigated variables.

METHODS

Study design

This is a cross-sectional study. The sample size was determined by including all participants that complied with the eligibility criteria. All participants were practitioners of RT with free-weights or machines and underwent three tests to assess balance, functionality, and isometric muscle strength. All tests were performed in a single assessment session in the following order: anthropometric measurements; Y Balance test; functional performance testing; and maximal isometric hip strength, respectively. All assessment was taken in a temperature-controlled environment (temperature 21° C, 65% relative humidity) by a Hygro-Thermometer with Humidity Alert (Extech Instruments, Massachusetts, EUA). All assessments occurred between 2:00 and 4:00 P.M. No clinical problems occurred during the study.

Participants

Thirty males were recruited and separated into two groups: Free-weights (age: 25.2 ± 5.2 years; height: 177.6 ± 7.5 cm; weight: 78.4 ± 6.1 kg; body fat: 15.2 ± 4.1%, n = 15) and Machines (age: 26.2 ± 4.9 years, height: 173.8 ± 9.7 cm, weight: 77.9 ± 5.9 Kg; body fat: 17.3 ± 5.8%, n = 15). Free-weights group presented training time of 5.1 ± 0.5 years, regular practice of RT 6.1 ± 1.4 days week and low aerobic training of 1.2 ± 0.2-day week with a total volume of 257.7 ± 9.2 minutes per week. However, Machine group presented training time of 5.2 ± 0.6 years, regular practice of RT 6.2 ± 1.2 days week and low aerobic training of 1.3 ± 0.2-day week with a total volume of 258.8 ± 9.8 minutes per week. Free-Weights group used an intensity between 60% and 80% 1RM and a routine of RT that engaged the whole body with resistance bands, free-weights and medicine balls (the training routine featured 85% closed kinetic chain exercises and 15% open kinetic chain exercises). Machine group also used intensity between 60% and 80% 1RM, but the training routine included only exercises on machines (the training routine featured 90% open kinetic chain exercises and 10% closed kinetic chain exercises). The characterization of the subjects' training routine was reported through a questionnaire.

Subjects with at least one year of RT experience were included to participate in the current study. Exclusion criteria included: (1) use of anabolic steroids, drugs, or medication with potential impact in physical performance (self-reported); (2) presence of lower limbs musculoskeletal injury in the past 6 months and (3) previous hip, knee, and/or ankle surgery. This study was approved by the Ethical Committee for Human Experiments of the Augusto Motta University Center, Rio de Janeiro, Brazil (CAAE: 46976821.5.0000.5235). The present study was conducted at the Rehabilitation Science Center, Augusto Motta University Center, Rio de Janeiro, Brazil. The study was performed in accordance with ethical standards in sport and exercise science research. All participants were informed of the experimental procedures and gave written informed consent prior to participation.

Anthropometric measurements

Body composition was measured following an 8-h overnight fast by bioelectrical impedance analysis using a device with built-in hand and foot electrodes (BIO 720, Avanutri, Rio de Janeiro, Brazil). The participants wore their normal indoor clothing and were instructed to stand barefoot in an upright position with both feet on separate electrodes on the device's surface and with their arms ab¬ducted and both hands gripping two separate electrodes on each handle of the device. All biometric measurements were carried out in an air-conditioned room (21°C).[9]

Y Balance test

The Y Balance Test (YBT) is a dynamic stability test considered efficient and clinically applicable to provide an accurate assessment of the lower limb neuromuscular control. The YBT Kit (Functional Movement Systems®, Chatham, USA) was used for analysis. The kit consisted of three connected cylindrical tubular plastic bars marked in half centimeter increments. Each bar has a moveable indicator plate, which the subject moves by pushing with their foot/toes without bearing weight on the indicator.

Initially, all participants positioned themselves on the center footplate, with the distal aspect of the foot at the starting line. Thus, while maintaining single leg stance on the leg, the subject reached with the free limb the anterior, posteromedial, and posterolateral directions in relation to the stance foot for pushing the indicator box as far as possible. Participants completed three consecutive trials for each reach direction and to reduce fatigue subjects altered limbs between each direction. Prior to the test, all participants performed six practice trials to minimize the influence of a learning effect. The YBT was performed dynamically on the dominant (DL) and the nondominant leg (NDL). The DL was defined as the preferred leg for kicking a ball, since this definition had proven most effective in determining interlimb differences in unipedal postural control.

Attempts were discarded and repeated when the subject didn't maintain unilateral stance on the platform, didn't maintain reach foot contact with the reach indicator on the target area while the reach indicator is in motion, used the reach indicator for stance support, or didn't return the reach foot to the starting position under control. The maximal distance reached after three successful trials in each direction was recorded at the baseline by the rater. Subject's lower limb reach was normalized from leg length, which was measured from the anterior superior iliac spine to the most distal portion of the medial malleolus.

Single leg step down test (SLSD test)

SLSD test started with individuals stood on an 8-inch wooden box, assuming a single-limb stance, hands in the hip and performing a squat that required the heel of the free leg to contact a scale on the floor to confirm a successful trial. They were required to contact a scale but not exceed 10% of body weight to prevent weight transfer off of the test limb. Upon contacting the scale, they returned to the starting position. Individuals were asked to complete as many step-downs as possible in 60 s. Step downs were not counted if the person did not contact a scale, transferred > 10% of body weight onto their free limb when contacting the scale, or did not fully return to the starting position.[9]

Single leg hop test (SLH test)

The functional performance was assessed with the single leg hop test (SLH) performed bilaterally (DL and NDL). Subjects, with footwear, positioned themselves single leg 30 cm behind of the first photocell beam (Brower Timing System, Salt Lake City, 174 UT, USA; accuracy of 0.01 sec). For the time record, subjects covered as fast as possible a 6-m distance that was timed by the second photocell beam (Figure 1). The test was repeated three times for both legs and a mean score of the three trials was then calculated. The subjects rested for 30 secs between the trials. Prior to SLH test, participants conducted a 10-min mobility and stability exercises. Verbal encouragement was always provided, and no subjects were excluded through injury during the experimental procedure. This test it was valid when it exhibits reliability that is higher than 0.90.

Maximal isometric hip strength

Maximal isometric hip strength (MIHS) was tested for the hip abductor and extensor muscle groups using a hand-held dynamometer in both leg (Lafayette Manual Muscle Tester Model 01163; Lafayette Instrument Company, Lafayette, IN, USA). Isometric strength assessments were performed on both lower limbs. The hip abductor and extensor muscle in the DL and NDL were tested isometrically. The hip abductor muscle group was tested in lateral decubitus with the hip in the neutral position. The handheld dynamometer was placed 5 cm proximal to the lateral epicondyle of the femur in a perpendicular position to the thigh (Figure 2A). The hip extensor muscle groups were tested in a prone position with the hip placed in neutral position. For hip extensors, the handheld dynamometer was placed 5 cm proximal to the posterior joint line of the knee in a perpendicular position to the thigh (Figure 2B).

Figure 1. Schematic diagram of the single-leg hops for time test.

Peak isometric strength was assessed three times for each participant and highest value of the three trials was used in the analyses and normalized to body mass (kilogram per kilogram). Participants were instructed to perform maximal effort against the dynamometer avoiding sudden movements, in order to build to isometric maximal effort over a 5-s period. The participants rested for 60 sec between the trials. All tests (i.e., isometric contractions of the hip abductor and extensor) used a five-minute recovery between them. The difference between DL and NDL peak isometric strength of the hip abductor and extensor muscle groups was analyzed. Verbal encouragement was always provided, and no subjects were excluded through injury during the experimental procedure. All measurements were performed by a single experienced researcher and intra-rater reliability was higher than 0.90.

Statistical Analysis

All data are presented as mean ± standard deviation. Statistical analysis was initially performed using the Shapiro–Wilk normality tests and the homoscedasticity test (Bartlett criterion). To test the reproducibility between the tests, the intraclass correlation coefficient (ICC) was used. Two-way analysis of variance (ANOVA) was used to test for main and interaction effects of the group (free-weight vs. machines group) and timing of measurement for each outcome variable independently (DL and NDL) and the post hoc Bonferroni was used to possibility a statistically significant. The effect size (ES) was assessed using Cohen's *d*. Values of $d<0.1$, from 0.1 to <0.20, from 0.20 to <0.50, from 0.50 to <0.80, and ≥0.80 were considered as trivial, small, moderate, large and very large, respectively.The level of statistical significance was set at an alpha level of $p<0.05$ using GraphPad Prism® software (Prism 6.0, San Diego, CA, USA).

RESULTS

All analyzed data presented normal distribution. The subjects presented an average analogical value of perceived exertion of 5 after the assessments. The two-way ANOVA yielded main effects for group in the anterior ($F_{1,22}$= 12.11, $p<.002$), posteromedial

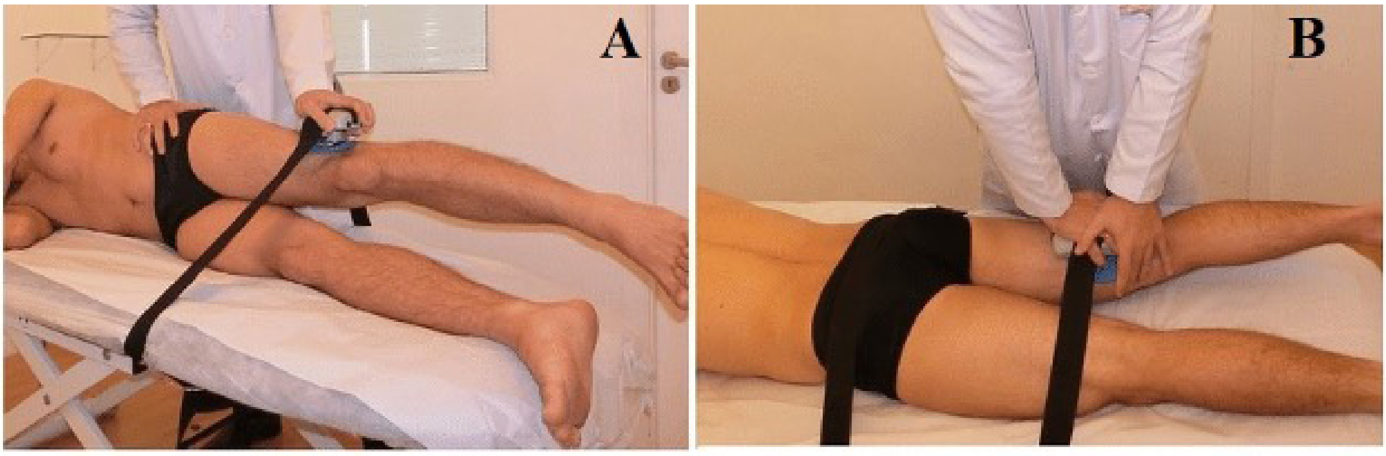

Figure 2. hip abductor Strength test; A, hip extensor Strength test; B.

($F_{1,22}$= 16.87, p<.0005), posterolateral ($F_{1,22}$= 15.97, *p*<.0006) and composite ($F_{1,22}$= 21.39, *p*<.0001) such that Bonferroni post- hoc showed significant differences in performance during YBT between free-weight vs. machines group for both legs (DL and NDL) (Table 1).

Table 2 compares the performance during SLSD and SLH test among males trained with free-weight vs. machines. SLSD test main effects for groups ($F_{1,22}$= 17.72, *p*<.0004) demonstrating better functional performance in the free-weight group when compared to machines group for both legs (DL and NDL) (Table 2). SLH test showed main effects for groups (Second: $F_{1,48}$= 87.91, *p*<.0001; m/s: $F_{1,48}$= 122.90, *p*<.0001; km/h: $F_{1,48}$= 122.50, *p*<.0001) in the free-weight group for both legs (DL and NDL) (*p*<.001) (Table 2). In addition, number of jumps ratio also showed main effects for groups ($F_{1,48}$= 54.00, *p*<.0001), such that Bonferroni post- hoc showed significant differences (*p*<.001) between free-weight vs. machines group for both legs (DL and NDL) (Table 2).

Table 3 compares the MIHS among males trained with Free-weight vs. Machine. Respectively, absolute ($F_{1,22}$= 12.62, *p*<.001; $F_{1,22}$= 22.34, *p*<.0001) and strength ratio ($F_{1,44}$= 16.25, *p*<.0002; $F_{1,44}$= 28.97, *p*<.0001) isometric muscle strength of hip abduction and extension showed main effects for groups demonstrating that it was significantly lower in the machines when compared to the free-weight group for both legs (DL and NDL) (Table 3).

Table 1. Performance during Y Balance test among male trained with free-weight vs. machines (n = 30).

		Free-weight	Machines	95% CI	p<	ES (a.u)
Anterior (cm)	DL	69.62 ± 6.54	62.45 ± 5.71	7.16 (0.50 to 13.82)	< 0.005	1.31 (very large)
	NDL	72.08 ± 5.25	63.45 ± 10.02	8.622 (1.96 to 15.28)	< 0.001	1.12 (very large)
Posteromedial (cm)	DL	113.1 ± 8.21	101.2 ± 10.56	11.90 (4.24 to 19.54)	< 0.001	1.24 (very large)
	NDL	114.5 ± 8.35	103.4 ± 3.29	11.10 (3.44 to 18.75)	< 0.001	1.70 (very large)
Posterolateral (cm)	DL	108.8 ± 5.75	96.82 ± 10.12	12.03 (3.21 to 20.84)	< 0.001	1.46 (very large)
	NDL	109.5 ± 12.53	97.73 ± 7.40	11.81 (2.99 to 20.63)	< 0.001	1.14 (very large)
Composite (cm)	DL	291.4 ± 15.76	260.5 ± 18.63	30.93 (13.21 to 48.65)	< .001	1.79 (very large)
	NDL	296.2 ± 22.70	264.5 ± 16.93	31.70 (13.98 to 49.42)	< 0.001	1.58 (very large)

Table 2. Performance during SLSD and SLH test among male trained with free-weight vs. machines (n = 30).

		Free-weight	Machines	95% CI	p<	ES (a.u)
SLSD test (repetitions)	DL	54.1 ± 6.88	39.8 ± 11.15	14.34 (5.60 to 23.07)	< 0.001	1.55 (very large)
	NDL	56.4 ± 8.25	40.2 ± 10.41	16.19 (7.45 to 24.92)	< 0.001	1.72 (very large)
SLH test (sec.)	DL	1.84 ± 0.10	2.47 ± 0.34	0.63 (0.39 to 0.86)	< 0.001	2.81 (very large)
	NDL	1.85 ± 0.09	2.56 ± 0.36	0.71 (0.48 to 0.95)	< 0.001	2.70 (very large)
SLH test (m/s)	DL	3.27 ± 0.18	2.47 ± 0.34	-0.79 (-1.04 to -0.55)	< 0.001	3.57 (very large)
	NDL	3.25 ± 0.16	2.38 ± 0.34	-0.86 (-1.11 to -0.62)	< 0.001	3.89 (very large)
SLH test (km/h)	DL	11.77 ± 0.66	8.89 ± 1.23	-2.87 (-3.76 to -1.98)	< 0.001	2.96 (very large)
	NDL	11.69 ± 0.58	8.57 ± 1.24	-3.12 (-4.00 to -2.23)	< 0.001	3.29 (very large)
Number of jumps	DL	3.23 ± 0.44	4.38 ± 0.51	1.15 (0.69 to 1.61)	< 0.001	2.53 (very large)
	NDL	3.30 ± 0.48	4.23 ± 0.60	0.92 (0.46 to 1.38)	< 0.001	1.82 (very large)

SLSD test = single leg step down test; SLH test = single leg hop test

Table 3. Performance of MIHS (absolute and strength ratio) among males trained with Free-weight vs. Machine group (n =30).

		Free-weight	Machines	95% CI	p<	ES (a.u)
Hip abductor strength (kg)	DL	20.18 ± 3.30	16.18 ± 1.19	4.00 (1.51 to 6.48)	< 0.001	1.62 (very large)
	NDL	20.06 ± 3.32	16.94 ± 1.51	3.12 (0.64 to 5.60)	< 0.05	1.20 (very large)
Hip abductor strength ratio (kg/kg)	DL	4.91 ± 0.44	4.01 ± 0.82	-0.90 (-1.55 to -0.26)	< 0.01	1.42 (very large)
	NDL	4.71 ± 0.47	4.02 ± 0.82	-0.67 (-1.32 to -0.03)	< 0.05	1.10 (very large)
Hip extensor strength (kg)	DL	23.68 ± 2.70	18.59 ± 3.61	5.08 (2.34 to 7.83)	< 0.001	1.60 (very large)
	NDL	24.32 ± 2.73	19.02 ± 2.44	5.30 (2.56 to 8.04)	< 0.001	2.07 (very large)
Hip extensor strength ratio (kg/kg)	DL	4.34 ± 1.11	3.33 ± 0.35	1.01 (0.42 to 1.60)	< 0.001	1.24 (very large)
	NDL	4.16 ± 0.67	3.24 ± 0.24	0.91 (0.32 to 1.50)	< 0.01	2.01 (very large)

MIHS = maximal isometric hip strength.

DISCUSSION

This study aimed to assess the neuromuscular and functional responses in males trained with free-weight vs. machines. The main results obtained with this study were that (a) Free-weight group showed greater performance during YBT than machine group for both legs (DL and NDL); (b) Free-weight group revealed better performance during single leg step down and single leg hop test for both legs (DL and NDL); and (c) Free-weight group showed greater isometric muscle strength of the hip abductor and extensor muscle during the assessment of the maximal isometric muscle strength testing.

In the scientific literature, some studies demonstrated the efficiency of RT in improving balance from young to old [12-15], but the absence of data relating neuromuscular and functional performance between free weights vs. machines supports the need for additional studies in this area. Ours results confirmed that males trained with machines had limited performance in the balance during YBT. A possible explanation might be that the exercises on the machines contribute with movements made only in a single plane of motion and that ballistic movements are impossible to perform.[2,10] Conversely, free-weights exercises are compound variable resistance that provides a load which changes to match the ability of the musculoskeletal lever system to produce force throughout the range of motion.[10,16] Thus, free-weights exercises combine upper, lower limbs and trunk promoting constant fine and gross motor adaptations, corrections of the ongoing movement, increase of the ground reaction forces and improving the balance.[6,12] In addition, a current study showed that free weights seem to be the more effective RT method to improve inhibitory control.[6] The improve inhibitory control enable the control attention (involves focus and selective attention) and cognitive inhibition (related to the ability to inhibit and select specific thoughts and memories) associated with improved balance.[12,17,18,19] Contrary, participants with low inhibitory control during dynamic postural control show higher center of pressure path lengths, which is indicative of a possible balance deficit.[17,18]

The functional performance tests require agility to better represent functional movements necessary for athletic participation. Thus, the functional performance tests may be more difficult to perform with decreased balance, mobility, and muscle strength of the lower limbs because the lower limbs are an important part of the closed-kinetic-chain movement.[6,9,10] Ours results showed better performance to Free-Weights group versus the Machines group during SLSD and SLH test. In accordance with our results, current studies have shown better performance during functional performance tests in practitioners of RT with free-weights, which showed a better control of sagittal plane movements and musculoskeletal injury prevention.[6,9,10] Indeed, the lower performance of the machines group makes us hypothesize that due to weakness of the posterolateral hip complex and knee extensor musculature contribute with a lower extremity kinematic pattern consisting of hip adduction, internal rotation and knee valgus. [9] Thus, machines group may use a stiffer landing strategy during functional performance tests by decreasing the hip and knee flexion during several tasks, overloading the knee extensor mechanism, and increasing the risk of knee injuries.[20-22] In addition, it has been observed that limitations in the ankle-dorsiflexion range of motion (ROM) may contribute to a stiff landing with less flexion at the ankle and knee during functional performance tests.[9,10,23] Consequently, limited ankle dorsiflexion ROM (because of a tight soleus, gastrocnemius, and/or capsular tissue) is associated with persisting deficits in explosive leg power, agility, and proprioception in males trained with machines.[10] In general, the free-weights exercise is a multi-joint movement with controlled co-contractions of synergistic and antagonistic muscles associated with minors anterior-posterior shear forces, there is less likelihood of an injury and better functional performance.[9,10,21]

The ability of force generation is related to the transverse section size, motor unit recruitment and action of synergist muscles.[2,12] Thus, the quantification of muscle strength becomes an essential component of the neuromuscular assessment being an important component of fitness, physical performance and reduction of the risk of injury.[24,25] Particularly in relation to hip muscles, the decreased strength of the hip musculature contributed with decreases the ability to stabilize the knee, resulting in a faulty alignment of the lower extremity, reduce of dynamic control of the knee, noncontact anterior cruciate ligament injury and linked to repetitive injuries such as iliotibial band friction syndrome and patellofemoral pain syndrome.[23,25,26] But there is a lack of studies comparing the isometric hip muscle strength among males trained with free weights vs. machines. Specifically, on the MIHS test for hip abduction and extension, our results showed that males trained with free-weight had greater production of isometric strength than machines group for both legs. A possible explanation for these results may be related the combination of ground reaction forces, intermuscular coordination, activation of synergistic muscles, ligamentous forces, and muscular/tendon forces throughout all lower extremity joints that are interrelated during free-weight exercises.[2,27,28] However, it has been observed that free-weight training protocols contribute with morphological and physiological changes that include increases in the size of the axon, the number of functional synapses, the size of the neuromuscular junction, and the enhancement of multiple fibre summation.[30,31] Collectively, these adaptations enhance neuromuscular efficiency, optimizing the expression of strength and power muscle. In addition, the strengthening of the hip muscles may cause a change in hip-knee flexion ratio, ultimately reducing the load placed on the patellar tendon and risk of knee injuries.[23,28] On the other hand, individuals with hip-muscle weakness adopt altered movement strategies to reduce mechanical demands on the hip, subjecting the knee joint to higher loading and enhancing the risk of injuries.[32] Thus, free-weight exercises are effective to increase hip muscle strength and reduce knee overload, proposing that motor control, instead of only peak strength, might be an important variable to be trained to improve performance, lower extremity alignment and reduces the risk of injuries.

The assessment of the isometric muscle strength between DL and NDL may suffer imbalanced in subjects trained in machines because the increase in muscle activity contributes to the decrease of stability, asymmetry of muscle strength and may cause functional or even structural disproportionateness.[9,33,34] Our findings showed reduce of in isometric muscle strength for Hip abductor and extensor muscles during the MIHS test in machine group. Some studies report that reduces of muscle strength contribute to loss of muscle power, slower change of direction speed times, and increased risk of lower limb injuries.[9,33] Particularly, in relation to the lower strength of the hip extensor muscles it can limit hip flexion because hip extensors are recruited to resist the external hip flexor moment resulting from the gravity force acting on the trunk and pelvis, thus lowering the balance and increased risk of lower limb injuries.[35] On the other hand, hip abductor muscles weakness shown an increase in contralateral pelvic drop, femoral adduction, dynamic knee valgus and knee injuries.[23,25,26]

As limitations of the study, were indicated: (i) the absence of measures of physiological parameters such as cardiorespiratory parameters of exercise capacity of physical exertion, that would be interesting, but do not limit the answer to the aim of the study; and (ii) a surface electromyography analysis to further explain the mechanisms underpinning alterations in muscle recruitment among males trained with free-weights vs. machines. On the other hand, we recommend longitudinal studies are needed to define a cause-and-effect relationship among RT model, functional performance, isometric muscle strength and bilateral asymmetry.

CONCLUSION

In conclusion, this study showed greater balance, functional performance and isometric muscle strength measurements of hip abduction and extension in males trained with Free-weight. On the other hand, males trained with the machines showed lower functional performance, balance and lower muscle strength of hip abductors and extensors, consequently, higher risk of lower limb injuries. These data contribute to the qualitative and quantitative understanding between RT models (Free-weight vs. Machine) in the balance, functional performance and hip muscle strength. Thus, these assessments may be a helpful for coaches, physicians and physical therapists regarding neuromuscular performance and injury prevention.

CONFLICT OF INTEREST

The author states no conflict of interest.

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