Linear Motor Driven Leg-Press Dynamometer

Subjects: Rehabilitation

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Regarding the acute responses after leg-press strength training with or without serial stretch-loading stimuli, visible changes were observed in the muscle force, rate of force development, and hormonal concentrations between pre- and postmenopausal women (only one study). Long-term studies revealed different training adaptations after performing leg-press strength training with unique serial stretch-loading stimuli. A positive trend for leg-press strength training with serial stretch-loading was recorded in the young population and athletes; however, more variable training effects favoring one or the other approach were achieved in the older population.

Keywords: proprioception ; isokinetic ; strength ; power ; musculoskeletal injuries

1. Introduction

Currently, using the terms “machine” or “training device” in reference to training and rehabilitation is somewhat controversial and/or sensitive for many practitioners from many areas of sports training and medicine. Some object to the nonfunctionality of these devices, while others use these devices during training alone or during the rehabilitation process. However, in both the abovementioned areas of sports training and medicine, the employment of machines is widely accepted and can play an important role in various situations. For instance, before and after operation, injured athletes noticed various deficits in addition to the safer and more controllable environments during complex solution processes [1]. When referencing the term ‘machine’, we must understand that these machines have progressed over time and are now very sophisticated, with multiple functions, modes, and outcomes, especially in terms of rehabilitation, where they accelerate recovery after injuries, operations, and other health-related complications [2]. In particular, robots are frequently applied for the rehabilitation of upper and lower extremities, and they can include grounded and wearable exoskeletons and grounded end-effector devices for controlling single or multiple joints. However, this area requires further exploration due to the limited number of studies [3]. Among many other sophisticated machines, the researchers' laboratory has developed in collaboration with the University of Vienna a linear motor-driven leg press dynamometer (**Figure 1**) that presents a unique serial stretch loading mode that allows for the generation of force peaks during exercise.

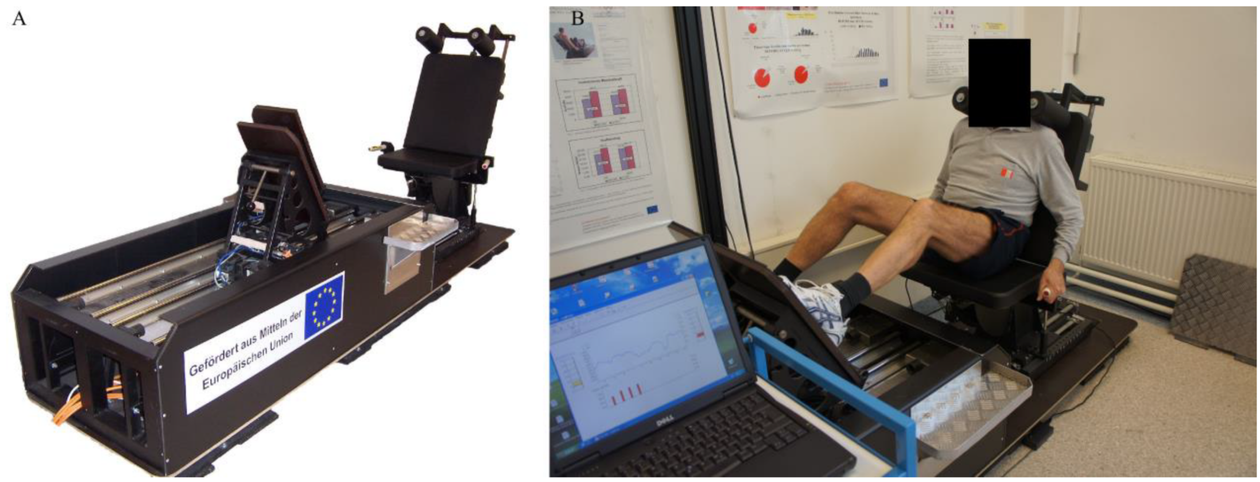

Figure 1. Represents unique linear motor-driven leg press dynamometer (**A**) and position during testing/training (**B**).

Strength and power are two factors that affect sports performance, and they are also the subject of wider research by many researchers, mainly in connection with the elderly population and/or rehabilitation [4][5][6], which is one of the reasons that led us to build a unique linear motor-driven leg press dynamometer. The main aim was to build a diagnostic and training device that could be used for multiple purposes in both younger and older subjects as well as for rehabilitation. The uniqueness of this device lies in the fact that it can generate force peaks by rapid changes in the direction or velocity of the movement during the concentric and eccentric phases of the movement.

2. Leg Press Used for Testing and Acute Responses

Five studies used a leg press device as a testing device only [7][8] or in combination for testing and determining the acute effects after a strength loading protocol [7][9][10][11]. In the study of Sedliak et al. [7], leg presses were used to test the bilateral MVC force before and after the training program. In this study, acute responses after bilateral isokinetic leg extensions were monitored. Except for these two studies, a leg press was used for both testing and as an acute loading protocol in the remaining studies. Altogether, when summarizing all these studies, all possible modes were used for testing and acute loading, including isometric, isokinetic, isoinertial (constant), and isokinetic with SSL stimuli. Only two studies used this device to directly compare acute responses after isokinetic strength training with SSL stimuli and without them [10][11]. Kovárová et al. [10] compared the acute responses of the isokinetic bilateral strength protocol with SSL stimuli and the isoinertial protocol (75% 1RM) on bone metabolism outcomes (bone alkaline phosphatase and sclerostin). Their results indicate no significant effect of any of the strength protocols. It should be noted that the results may be hindered by the number of subjects in the study, which was relatively low (n = 7), and the selected markers of bone metabolism; moreover, for minor changes, other parameters could be more appropriate (e.g., β-CTX, P1NP, and others) [12]. In another study, Vajda et al. [11] also compared acute responses after isokinetic bilateral strength training, including SSL stimuli and isoinertial (constant) resistance (75% 1RM), in pre- and postmenopausal women. The results indicated possible different acute responses of muscle force, RFD, and hormonal concentrations between pre- and postmenopausal women after the protocol with SSL and isoinertial training. MVC and RFD were significantly decreased after the protocol with SSL in premenopausal women and significantly decreased in postmenopausal women after the isoinertial protocol. The hormone concentration was affected after both protocols only in the premenopausal women. A possible explanation may be age-dependent effects because some data showed that middle-aged women react differently to loading strategies (more resistant to fatigue than younger women) [13]. However, this supposition needs to be further examined due to the limited number of studies that have reported isokinetic strength training (whether acute or long-term) alone and because of the unique nature of the SSL stimuli, compared to the traditional training provided to postmenopausal women and other populations.

3. Leg Press Used for Training and Its Effect on Various Outcomes

Eight studies used leg press devices for training purposes, and unique SSL stimuli were used directly during the training process [14][15][16][17][18][19][20][21]. Two studies directly compared LP strength training with and without SSL stimuli [14][15], five studies compared LP strength training with SSL stimuli and ES (electrical stimulation) training [16][17][18][19][21], and one study also compared LP strength training with SSL stimuli and standard physiotherapeutic training [12].

For instance, Cvečka et al. [14] compared LP strength training with and without SSL stimuli in a group of young men who trained regularly. The results of their study suggest that the group that trained with the unique SSL stimuli achieved almost double the increments in almost all measured outcomes, except for RFD, maximal concentric force, and CMJ %. However, there was no between-group statistical significance in any of the outcomes measured. Similar results were obtained in the study by Kern et al. [15], who also compared LP strength training with and without SLL stimuli in a group of young men who trained regularly. The results suggested no significant differences between the groups in muscular strength or jump and sprint performance. However, only the group with SSL stimuli significantly improved the RFD and 30 m sprint time results and increased the fast muscle fiber diameter. The above studies indicate that using unique SSL stimuli that can generate force peaks may have a more beneficial effect or produce trends toward greater improvements compared to standard stimuli in young males.

The effects of training between LP strength training with SSL stimuli and ES training were only determined in elderly populations. The results from these studies were somewhat similar, with no significant differences between the groups, as shown in **Table 1**. However, few studies clearly showed the beneficial effects of one training alternative. For instance, Šarabon et al. [17] compared the effects of LP strength training with SSL stimuli and ES training in seniors on static balance. The results suggest that LP strength training with SSL stimuli led to significant CoP velocity improvement in all measured directions as well as anterior–posterior amplitude improvements compared to the ES group, where only the mediolateral CoP velocity was improved. However, no significant differences between groups were reported. In contrast, Zampieri et al. [19] compared LP strength training with SSL stimuli and ES training and showed that the ES group presented significant improvements in almost all measured outcomes compared to the LP SSL group (only chair raise test and 10 m fast walking test). Similarly, another study by Zampieri et al. [21] compared LP strength training with SSL stimuli and ES straining, and the results suggested that only the ES group presented significant improvements in isometric MVC torque, increased myofiber and mitochondria size, and upregulated IGF1 pan, IGF-1a, IGF-1b, and IGF-1c isoforms. The isokinetic LP SSL group only significantly induced IGF1b isoforms and significantly improved the chair raise test. Only one study [20] was focused on comparing the potential differences between LP strength training with SSL stimuli and standard physiotherapy training. As shown in **Table 1**, both groups improved all measured outcomes, with no significant differences between the groups.

Table 1. Long-term training studies using a leg press dynamometer during strength training.

Study	Sample	Design	Measures	Intervention	Results
Cvečka et al. [14]	Young well-trained males Isokinetic LP SSL group (*n* = 17, 23.3 ± 2.6 years) Isokinetic LP group (*n* = 16, 22.6 ± 2.5 years)	Randomized controlled trial Two groups pre/post design	Isometric bilateral MVC force on a leg press device Isokinetic bilateral maximal and mean force in concentric and eccentric phase of leg press exercise Isometric bilateral RFD (200 ms) on a leg press device CMJ height	Duration 8 weeks Trained 3 x/week Isokinetic bilateral LP SSL group - 6 sets and 6 reps - 0.3 m/s and 0.2 m/s extension and flexion velocity, respectively - 5 mm SSL counter movements Isokinetic bilateral LP group - 9 sets and 6 reps (higher volume compensate for time loss due to SSL mode duration in the LP SSL group) - 0.3 m/s and 0.2 m/s extension and flexion velocity, respectively	Both groups showed sig. increases in MVC (LP SSL: 48.1%, $p < 0.01$; LP group: 24.8%, $p < 0.01$) RFD (LP SSL: 37.9%, $p < 0.05$; LP group: 31.4%, $p < 0.05$) and maximal concentric force (LP SSL: 45.4%, $p < 0.01$; LP group: 47.0%, $p < 0.01$). Mean concentric force sig. increased only in LP SSL (47.5%, $p < 0.01$) Maximal eccentric force sig. increased in both groups (LP SSL: 43.6%, $p < 0.01$; LP group: 24.7%, $p < 0.01$) Mean eccentric force sig. increased in both groups (LP SSL: 43.5%, $p < 0.01$; LP group: 24.9%, $p < 0.05$) CMJ sig. increased only in the LP SSL group (7.2%, $p < 0.05$) Isokinetic LP SSL achieved almost double the % increments in MVC, mean concentric force, maximal eccentric force and mean eccentric force compared to the isokinetic LP group only RFD, maximal concentric force and CMJ % improvements were similar between the groups

Study	Sample	Design	Measures	Intervention	Results
Kern et al. [15]	Young male athletes (n = 29, 22.95 ±.2 years) Isokinetic LP SSL group (23.1 ± 2.7 years) Isokinetic LP group (22.6 ± 3.9 years)	Randomized controlled trial Two groups pre/post design	Isometric unilateral MVC force and RFD (0–50 ms) on a leg press device SJ height 30-m sprint time Muscle biopsies - fiber type distribution and diameter Gene expression	Duration 8 weeks Trained 3 x/week Unilateral or bilateral training is not defined Concentric velocity was 0.3 m/s and eccentric one 0.2 m/s Isokinetic LP SSL group - 6 sets of 6 reps with maximal effort including short countermovement (0.5 cm) every 2 cm Isokinetic LP group - standard isokinetic mode with 6 sets and 8 reps (compensate time difference compared to the other group) • 2 min rest time between the sets	Both groups showed significantly improved isometric unilateral MVC force (LP SSL: 48.1%, $p < 0.01$; LP group: 24.8%, $p < 0.01$) Only the LP SSL group showed sig. improvements in the RFD (30.2%, $p < 0.001$), SJ height (7.4%, $p < 0.005$) as well as 30-m sprint time (−1.3%, $p < 0.05$) No significant differences between the groups in the strength outcomes, jump and sprit time Only the LP SSL group significantly increased fast muscle fiber diameter (9%, $p < 0.001$) - No changes in the LP group only - Changes were significantly higher in the LP SSL group compared to the LP group only ($p < 0.001$) LP SSL group showed sig. increases in IGF-1Ec (2-fold change, $p < 0.05$) and PGC-1α (228%, $p < 0.05$) • Significant downregulation of myostatin occurred only in the LP SSL group (4-fold change, $p < 0.0005$)

Study	Sample	Design	Measures	Intervention	Results
Kern et al. [16]	Seniors (gender not defined)Group 1 (Vienna): 2 subgroups - Isokinetic LP SSL group (*n* = 16, 74.93 ± 5.48 years) - ES group (*n* = 16, 73.20 ± 6.56 years) Group 2 (Bratislava): 2 subgroups -Isokinetic LP SSL group (*n* = 9, 71.12 ± 3.34 years) - ES group (*n* = 9, 70.41 ± 3.74 years)	Randomized controlled trial Four groups pre/post design	Unilateral knee extension - Isometric MVC force and RFD on a force chair 10 m fasted walking Chair raise TUG Stair test Dynamic balance Muscle biopsies - myofibers diameter	8–10 weeks of training (10 in Group 1, 8 in Group 2) Bilateral training Two subgroups (isokinetic LP SSL groups) performed a ST on the LP device with SSL mode One subgroup from each group (ES groups) performed home-based electrical stimulation Detailed training program is not specified	Group 1: LP SSL subgroup showed sig. improvements in all functional tests except for MVC force. ES subgroup showed sig. improvements in all functional tests except for dynamic balance Group 2: LP SSL subgroup showed sig. improvement in only the chair raise test (from 12.52 ± 1.98 to 10.12 ± 1.41 s, $p = 0.041$) while others remained unchanged. ES subgroup showed sig. improvements in also chair rise test (from 13.12 ± 2.60 to 11.25 ± 1.66 s, $p = 0.018$) Both groups and their subgroups showed sig. increases in myofiber diameter

Study	Sample	Design	Measures	Intervention	Results
Šarabon et al. [17]	Sedentary seniors (gender not defined) 74.3 ± 7.0 years Three groups: - Isokinetic LP SSL group (*n* = 28) - ES group (*n* = 27) - CON group (*n* = 19)	Randomized controlled trial Three groups pre/post design	30 s static balance - average velocity, amplitude, and frequency of CoP - total, medial-lateral, anterior-posterior direction	Duration 9 weeks Trained 3 x/week Bilateral training Isokinetic LP SSL group - velocity of the pedals was 0.3 m/s and 0.2 m/s for concentric and eccentric phase, respectively - every 8 mm was interrupted by a short stop that resulted in force peaks - 2–3 sessions/week - 4–5 sets/session - time/set from 8 to 14 s - ES group: anterior thigh stimulation (both legs) with frequency of 60 Hz - 45 contractions (3 × 15 reps, 2 sessions in the first 2 weeks) - 75 contractions (from week 3 to 9) CON group: continued in their normal daily activities	The Isokinetic LP SSL group showed sig. improvements in CoP velocity in anterior-posterior (from 14.4 ± 1.5 to 11.4 ± 1.1 mm/s, $p < 0.05$), medial-lateral (from 7.5 ± 0.7 to 6.1 ± 0.5 mm/s, $p < 0.05$) and total direction (from 17.6 ± 1.6 to 15.2 ± 1.2 mm/s, $p < 0.05$) as well as anterior-posterior amplitude (from 5.6 ± 0.5 to 4.9 ± 0.5 mm, $p < 0.05$) The ES group showed sig. improvements in medial-lateral CoP velocity (from 6.9 ± 0.7 to 5.6 ± 0.4 mm/s, $p < 0.05$) The CON group sig. worsened CoP anterior-posterior velocity (from 14.6 ± 1.7 to 16.1 ± 1.5 mm/s, $p < 0.05$)

Study	Sample	Design	Measures	Intervention	Results
Cvečka et al. [18]	Sedentary seniors Gender and age are not defined Two groups: - Isokinetic LP SSL group - ES group	Randomized controlled trial Two groups pre/post design	Isometric MVC torque on a chair dynamometer - bilateral or unilateral testing is not defined Chair rising test TUG 10 m walk test	Duration 8 weeks Bilateral or unilateral training is not defined Isokinetic LP SSL group - frequency of 16 and 14 Hz - 5 sets with 12–14 s of contraction time - 3 x/week ES group - knee extensors ES - 3 x/week - 3 sets of 10 min (first 2 weeks 3 sets of 6 min)	The LP SSL group showed sig. improvements in MVC torque (from 222 to 236 Nm, $p < 0.05$), chair rising test (from 12.5 to 10.4 s, $p < 0.05$), TUG (from 6.29 to 5.68 s, $p < 0.05$), 10 m walk test (from 5.06 to 4.80 s, $p < 0.05$), and postural stability test (data not shown) The ES group showed sig. improvements in MVC torque (from 232 to 248 Nm, $p < 0.05$), chair rising test (from 13.10 to 10.80 s, $p < 0.05$), TUG (from 7.61 to 6.96 s, $p < 0.05$), and 10 m walk test (from 5.96 to 5.52 s, $p < 0.05$) No sig. differences between the groups

Study	Sample	Design	Measures	Intervention	Results
Zampieri et al. [19]	Sedentary seniors (M/F) Isokinetic LP SSL group (*n* = 9, M = 5, F = 4, 71.8 ± 7.1 years) ES group (*n* = 16, M = 8, F = 8, 70.6 ± 2.8 years)	Randomized controlled trial Two groups pre/post design	Isometric MVC torque on a chair dynamometer Functional tests using "SFT battery" - TUG - Chair raise - 10 m habitual walking test - 10 m fast walking test Muscle biopsy including myofiber diameter Unilateral or bilateral testing is not specified	Duration 9 weeks Isokinetic LP SSL group - 3 x/week ES group - 3 x/week Detailed training program is not specified in both groups Unilateral or bilateral training is not specified	The isokinetic LP SSL group showed sig. improvements in chair rise test (from 10.95 ± 1.75 to 9.54 ± 1.92 s, $p < 0.05$) and 10 m fast walking test (from 1.90 ± 0.19 to 2.01 ± 0.23 s, $p < 0.005$) The ES group showed sig. improvements in isometric MVC torque (from 1.42 ± 0.34 to 1.51 ± 0.38 Nm, $p < 0.05$), TUG (from 8.42 ± 1.95 to 7.04 ± 1.09 s, $p < 0.0005$), chair rise test (from 13.85 ± 3.33 to 10.53 ± 3.63 s, $p < 0.005$), 10 m habitual walking test (from 1.20 ± 0.19 to 1.26 ± 0.18 s, $p < 0.05$) and 10 m fast walking test (from 1.58 ± 0.28 to 1.66 ± 0.24 s, $p < 0.05$) The isokinetic LP SSL group showed sig. decreases in slow (from 55.43 ± 17.33 to 53.12 ± 16.06 μm, $p < 0.001$) and fast type myofiber diameter (from 48.96 ± 16.18 to 46.43 ± 15.96 μm, $p < 0.001$) The ES group showed sig. decreases in slow type myofiber diameter (from 50.30 ± 14.78 to 48.48 ± 16.67 μm, $p < 0.001$) but sig. increases in the fast type myofiber diameter (from 46.53 ± 14.04 to 47.54 ± 15.79 μm, $p < 0.001$)

Study	Sample	Design	Measures	Intervention	Results
Billy et al. [20]	Sedentary seniors (M/F) Total knee arthroplasty Isokinetic LP SSL group (*n* = 26, M = 9, F = 17, 64.9 ± 6.0 years) Physiotherapy group (*n* = 29, M = 9, F = 20, 68.3 ± 6.7 years)	Randomized controlled trial Two groups pre/post design	Isometric unilateral MVC peak force of leg extension on a leg press device Isometric unilateral MVC torque of knee extension on a force chair TUG Stair test Pain and function Active and passive range of motion	Duration 6 weeks Trained 2 x/week Unilateral training- involved and uninvolved leg Isokinetic LP SSL group - 4 to 6 sets of 22 to 25 s with SSL during concentric phase interrupted by a countermovement (1 to 2 cm backward) Physiotherapy group - physiotherapy training included cycling, manual and soft tissue therapy, ROM-exercises, isometric and dynamic strengthening exercises, and gait-retraining exercises - 1 to 3 sets of 10 to 15 reps with individualized intensity - duration of 1 session was 30 min	The LP SSL group showed sig. improvements in MVC force on a leg press device with involved leg (from 8.9 ± 0.77 to 10.3 ± 1.06 N/kg, $p < 0.05$), MVC on force chair with involved (from 0.8 ± 0.06 to 1.0 ± 0.09 Nm/kg, $p < 0.01$) and uninvolved leg (from 1.2 ± 0.09 to 1.2 ± 0.11 Nm/kg, $p < 0.01$) - The LP SSL group showed sig. improvements in all other functional outcomes Physiotherapy group showed sig. improvements in MVC force on a leg press device with involved leg (from 6.7 ± 0.54 to 9.1 ± 0.70 N/kg, $p < 0.05$), MVC on force chair with involved (from 0.7 ± 0.06 to 0.9 ± 0.06 Nm/kg, $p < 0.00$) and uninvolved leg (from 1.1 ± 0.08 to 1.2 ± 0.07 Nm/kg, $p < 0.01$) - The PT group showed sig. improvements in all other functional outcomes No sig. differences between the groups after training were recorded in any of the examined outcomes

Study	Sample	Design	Measures	Intervention	Results
Zampieri et al. [21]	Sedentary seniors (M/F) Isokinetic LP SSL group (*n* = 7, M = 4, F = 3, 70.1 ± 2.9 years) ES group (*n* = 10, M = 5, F = 5, 71.4 ± 7.1 years)	Randomized controlled trial Two groups pre/post design	Isometric MVC torque on a force chair Time to raise from a chair Muscle biopsies Gene expression Mitochondrial dynamics Unilateral or bilateral testing is not specified	Duration 9 weeks Trained 2–3 x/week Isokinetic LP SSL group - intensity approximately 90% of MVC - detailed training program of leg press training is not defined ES group - ES of the thigh quadriceps musculature of both legs at 60 Hz by 3.5-s train of impulses with 4.5-s off intervals - intensity: approximately 40% of MVC Unilateral or bilateral training is not specified	The isokinetic LP SSL group showed sig. improvements in chair raise test ($p = 0.050$) but no sig. changes in MVC torque The ES group showed sig. improvements in MVC torque ($p = 0.026$) and chair raise test ($p = 0.036$) The ES group showed sig. increases in myofiber size (from 49.16 ± 15.80 to 51.01 ± 16.38 µm, $p < 0.0001$) The isokinetic LP SSL group showed sig. decreases in myofiber size (from 57.87 ± 19.17 to 55.21 ± 18.13 µm, $p < 0.0001$) Only the ES group showed sig. decreases in the atrophy factor ($p = 0.031$) The ES group showed sig. upregulation of IGF1 pan ($p = 0.001$), IGF-1a ($p = 0.001$), IGF-1b ($p = 0.014$), IGF-1c isoforms ($p = 0.013$) The Isokinetic LP SSL group showed sig. induction of IGF1b isoforms ($p = 0.002$) Only the ES group showed sig. increases in mitochondria size (from 72.3 ± 1.9 to 80.4 ± 2.5 $µm^2$, $p = 0.009$), although the mitochondria number sig. decreased (from 48.3 ± 1.3 to 38.6 ± 1.2 $µm^2$, $p = 0.0001$) - No changes in the isokinetic LP SSL group

Note: *n* = sample size, MVC = maximal voluntary contraction, CMJ = countermovement jump height, SJ = squat jump height, ES = electrical stimulation group, CoP = center of pressure, µm = micrometer, s = seconds, m/s = meters per seconds, sig. = significant, RFD = rate of force development, N = Newton, Nm = Newton meter, M = male, F = female, TUG = timed up and go test.

In the above studies, different training adaptations can be seen after performing LP strength training with unique SSL stimuli. Similar training effects with a positive trend for the LP SSL group were recorded in young males [14] and athletes [15]; however, more variable training effects favoring one or the other approach were achieved in the older population. It should also be noted that only the ES protocol was performed in the senior population; thus, direct comparison of strength training with and without SSL cannot be performed.

Altogether, the studies show that using an LP device with or without SSL stimuli seems to be a very useful alternative because it offers several modes that can be adjusted according to the subject's needs (i.e., training and testing mode—isokinetic, isometric, isoinertial, SSL mode, bilateral or unilateral adjustment). As shown in **Table 1**, except for two studies, only an older population was included. This finding suggests that the mentioned LP device with SSL stimuli may be a suitable alternative for the rehabilitation process, which is currently very complex, and strength training overall has its own place in the modern physiotherapy approach [22]. This finding has been documented by numerous research studies, such as the inclusion of strength training after total knee arthroplasty [23][24][25].

References

1. Yong-Seok, J. Usefulness of measuring isokinetic torque and balance ability for exercise rehabilitation. J. Exerc. Rehabil. 2015, 11, 65–66.
2. Mavroidis, C.; Nikitczuk, J.; Weinberg, B.; Danaher, G.; Jensen, K.; Pelletier, P.; Prugnarola, J.; Stuart, R.; Arango, R.; Leahey, M.; et al. Smart portable rehabilitation devices. J. Neuroeng. Rehabil. 2005, 2, 18.
3. Gassert, R.; Dietz, V. Rehabilitation robots for the treatment of sensorimotor deficits: A neurophysiological perspective. J. Neuroeng. Rehabil. 2018, 15, 46.
4. Hamar, D. Universal linear motor driven Leg Press Dynamometer and concept of Serial Stretch Loading. Eur. J. Transl. Myol.-Basic Appl. Myol. 2015, 25, 215–219.
5. Wang, E.; Nyberg, S.K.; Hoff, J.; Zhao, J.; Leivseth, G.; Tørhaug, T.; Husby, O.S.; Helgerud, J.; Richardson, R.S. Impact of maximal strength training on work efficiency and muscle fiber type in the elderly: Implications for physical function and fall prevention. Exp. Gerontol. 2017, 91, 64–71.
6. Caserotti, P.; Aagaard, P.; Larsen, J.B.; Puggaard, L. Explosive heavy-resistance training in old and very old adults: Changes in rapid muscle force, strength and power. Scand. J. Med. Sci. Sports 2008, 18, 773–782.
7. Sedliak, M.; Zeman, M.; Buzgó, G.; Cvecka, J.; Hamar, D.; Laczo, E.; Okuliarova, M.; Vanderka, M.; Kampmiller, T.; Häkkinen, K.; et al. Morphological, molecular and hormonal adaptations to early morning versus after-noon resistance training. Chronobiol. Int. 2018, 35, 450–464.
8. Billy, W.; Sarabon, N.; Löfler, S.; Franz, C.; Wakolbinger, R.; Kern, H. Relationship between strength parameters and functional performance testsin patients with severe knee osteoarthritis. PM R. 2019, 11, 834–842.
9. Sedliak, M.; Zeman, M.; Buzgó, G.; Cvečka, J.; Hamar, D.; Laczo, E.; Zelko, A.; Okuliarová, M.; Raastad, T.; Nilsen, T.S.; et al. Effect of time of day on esistance exercise-induced anabolic signaling in skeletal muscle. Biol. Rhythm Res. 2013, 44, 756–770.
10. Kovárová, J.; Hamar, D.; Sedliak, M.; Cvečka, J.; Schickhofer, P.; Böhmerová, Ľ. Acute Response of Bone Metabolism to Various Resistance Exercises in Women. AFEPUC 2015, 55, 11–19.
11. Vajda, M.; Kovarova, J.; Okuliarova, M.; Cvecka, J.; Schickhofer, P.; Bohmerova, L. Acute hormonal and neuromuscular response to various loading in young pre- and middle-aged postmenopausal women. Gazz. Med. Ital. Arch. Sci. Med. 2017, 177, 443–451.
12. Scott, J.P.; Sale, C.; Greeves, J.P.; Casey, A.; Dutton, J.; Fraser, W.D. The role of exercise intensity in the bone metabolic response to an acute bout of weight-bearing exercise. J. Appl. Physiol. 2011, 110, 423–432.
13. Avin, G.K.; Law, F.L. Age-related differences in muscle fatigue vary by contraction type: A meta-analysis. Phys. Ther. 2011, 91, 1153–1165.
14. Cvecka, J.; Hamar, D.; Trimmel, L.; Vogelauer, M.; Bily, W. Einfluss von serial stretch loading auf die Effektivität des isokinetischen. BAM 2009, 19, 175–180.
15. Kern, H.; Pelosi, L.; Coletto, L.; Musaro, A.; Sandri, M.; Vogelauer, M.; Trimmel, L.; Cvecka, J.; Hamar, D.; Kovarik, J.; et al. Atrophy/hypertrophy cell signaling in muscles of young athletes trained with vibration-al-proprioceptive

stimulation. Neurol. Res. 2011, 33, 998–1009.

16. Kern, H.; Loefler, S.; Hofer, C.; Vogelauer, M.; Burggraf, S.; Grim-Stieger, M.; Cvecka, J.; Hamar, D.; Sarabon, N.; Protasi, F.; et al. FES Training in Aging: Interim results show statistically significant improvements in mobility and muscle fiber size. Eur. J. Transl. Myol. 2012, 22, 61–67.
17. Nejc, S.; Loefler, S.; Cvecka, J.; Sedliak, M.; Kern, H. Strength training in elderly people improves static balance: A randomized controlled trial. Eur. J. Transl. Myol. 2013, 23, 85–89.
18. Cvecka, J.; Tirpakova, V.; Sedliak, M.; Kern, H.; Mayr, W.; Hamar, D. Physical activity in elderly. Eur. J. Transl. Myol. 2015, 25, 249–252.
19. Zampieri, S.; Mosole, S.; Löfler, S.; Fruhmann, H.; Burggraf, S.; Cvečka, J.; Hamar, D.; Sedliak, M.; Tirptakova, V.; Šarabon, N.; et al. Physical exercise in Aging: Nine weeks of leg press or electrical stimulation training in 70 years old sedentary elderly people. Eur. J. Transl. Myol. 2015, 25, 237–242.
20. Bily, W.; Franz, C.; Trimmel, L.; Loefler, S.; Cvecka, J.; Zampieri, S.; Kasche, W.; Sarabon, N.; Zenz, P.; Kern, H. Effects of Leg-Press Training with Moderate Vibration on Muscle Strength, Pain, and Function After Total Knee Arthroplasty: A Randomized Controlled Trial. Arch. Phys. Med. Rehabil. 2016, 97, 857–865.
21. Zampieri, S.; Mammucari, C.; Romanello, V.; Bardberi, L.; Pietrangelo, L.; Fusella, A.; Mosole, S.; Gherardi, G.; Höfer, C.; Löfler, S.; et al. Physical exercise in aging human skeletal muscle increases mitochondrial calcium uniporter expression levels and affects mitochondria dynamics. Physiol. Rep. 2016, 4, e13005.
22. Shaw, I.; Shaw, S.B.; Brown, A.G.; Shariat, A. Review of the Role of Resistance Training and Muscu- loskeletal Injury Pre-vention and Rehabilitation. Gavin J. Orthop. Res. Ther. 2016, 1, 1–5.
23. Nguyen Ch Lefèvre-Colau, M.M.; Poiraudeau, S.; Rannou, F. Rehabilitation (exercise and strength training) and osteoar-thritis: A critical narrative review. Ann. Phys. Rehabil. Med. 2016, 5, 190–195.
24. Jakobsen, T.L.; Kehlet, H.; Husted, H.; Petersen, J.; Bandholm, T. Early Progressive Strength Training to Enhance Recovery After Fast-Track Total Knee Arthroplasty: A Randomized Controlled Trial. Arthritis Care Res. 2014, 66, 1856–1866.
25. Husby, S.V.; Foss, A.O.; Husby, S.O.; Winther, B.S. Randomized controlled trial of maximal strength training vs. standard rehabilitation following total knee arthroplasty. Eur. J. Phys. Rehabil. Med. 2018, 54, 371–379.