Effectiveness of Focal Muscle Vibration in Neuromotor Hypofunction

Subjects: Neurosciences

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Adequate physical recovery after trauma, injury, disease, a long period of hypomobility, or simply ageing is a difficult goal because rehabilitation protocols are long-lasting and often cannot ensure complete motor recovery. Therefore, the optimisation of rehabilitation procedures is an important target to be achieved. The possibility of restoring motor functions by acting on proprioceptive signals by unspecific repetitive muscle vibration, focally applied on single muscles (RFV), instead of only training muscle function, is a new perspective, as suggested by the effects on the motor performance evidenced by healthy persons. The focal muscle vibration consists of micro-stretching-shortening sequences applied to individual muscles. By repeating such stimulation, an immediate and persistent increase in motility can be attained.

muscle vibration proprioception muscle spindle proprioceptive training

1. Introduction

Neuromotor hypofunction refers to a condition in which an individual has difficulty or limitations controlling and coordinating a movement and can affect various aspects of motor skills, from fine motor skills (such as writing, eating, buttoning a shirt) to gross motor skills (such as lifting weights, walking or running). The functional impairment consists of ‘negative symptoms’, such as asthenia, weakness, poor motor coordination and fatigue. These functional deficits can be induced by various neuromuscular diseases and by musculoskeletal trauma during daily, sporting and professional activities. For the latter, several individual characteristics are possible risk factors, such as age, poor fitness level, comorbidities, etc. Often, motor function may be restored after a long period of rehabilitation by providing impairment-specific intervention protocols. It should be noted that the motor and functional level obtained at the end of a rehabilitation period may not be sufficient to ensure full motor recovery. This is particularly true in sports, where full recovery of coordination and conditioning skills can be achieved with an additional conditioning period. An obvious limitation of exercise-based rehabilitation protocols is imposed by the individual’s functional residual, as well as expected individual compliance.

Optimisation of rehabilitation [1][2] is an area of study that always offers new topics, as research is constantly looking for protocols that reduce duration, avoid relapse and ensure full recovery of motor functions. A new direction of research suggests the possibility of acting on motor control in addition to or as an alternative to traditional exercise [3].

Reviews report evidence that sustained activation of the proprioceptive system can induce immediate improvements in motor abilities in healthy subjects [4][5][6]. Indeed, literature data show that improvements in muscle strength, motor task readiness, muscle power and movement fluidity and coordination can be achieved with proprioceptive stimulation, suggesting that this intervention be included in traditional rehabilitation programmes to improve subsequent functional motor deficits. These possibilities find important support in the consideration that motor movements and performance are largely based on proprioceptive input, upon which motor planning and execution are built and controlled [3]. On the other hand, proprioception deficits lead to profound alterations in motor execution, altering the control of postural reflexes, muscle tone and motor behaviour [7], as well as the spatial and temporal aspects of movement [8][9]. Although motor execution is supported by different sensory modalities (auditory, visual and tactile systems are involved), the proprioceptive system is considered the main source of information to plan and perform elementary and complex motor tasks. Improved proprioceptive processing could improve the accuracy of motor execution, as well as motor efficiency (i.e., muscle strength, fatigue), the latter being profoundly influenced by coordination. Therefore, an improvement of proprioceptive input could be a reasonable approach to improve or restore motor function. Furthermore, training the proprioceptive system does not require loading the skeletal system, avoiding one of the most relevant obstacles and allowing rehabilitation procedures to be anticipated, possibly preventing possible relapses.

2. Effects of RMV Stimulation on Motor Function

The twenty-two selected studies and their main points are summarised in **Table 1**. Subjects with poor motor function showed significant improvements in muscle strength after RMV stimulation [10][11][12][13][14][15][16][17][18][19][20][21][22][23][24][25][26][27] and in power [22][23][28][29][30]. Other less common outcomes expressing an improvement in function are improved joint mobility [31], positive electrophysiological changes in the spinal cord [13], reduced pain caused by insufficient joint stabilisation [17][20][22] and rate of strength development [27]. The after-effects were evident and statistically significant immediately after the end of the treatment. This finding, as well as the long persistence (up to 1 year after treatment), agrees with studies on healthy individuals previously reviewed [4][5][6].

Table 1. Main characteristics of the selected studies included in the review. NR: not reported. The outcome values at the end of the follow-up are reported (* $p < 0.01$; ** $p < 0.001$).

Study	Origin of the Deficit	Sbjts	FV Frequency & Amplitude	Single Application Duration & Repetition	Muscle Body Part Treated/Muscle Contraction	Tests	1st Test and Last Test	Maximal After-Effect
Brunetti et al., 2006 [10]	ACL reconstruction	30	100 Hz; 0.2–0.5 mm	10 min; 3 times a day during 3 consecutive days	Quadriceps/Yes	Stability (cop area, velocity); extensor muscle peak torque	24 h; 270 days	Reduction sway (closed eyes) -40% *; extensor peak force difference vibrated/not

Study	Origin of the Deficit	Sbjts	FV Frequency & Amplitude	Single Application Duration & Repetition	Muscle Body Part Treated/Muscle Contraction	Tests	1st Test and Last Test	Maximal After-Effect
								vibrated +25% *
Filippi et al., 2009 [28]	Ageing	60	100 Hz; 0.2–0.5 mm	11 min; 3 times a day during 3 consecutive days	Quadriceps/Yes	Stability (cop area, velocity); vertical jump height; muscle power	24 h; 90 days	Power ≈ +50% *; height ≈ +90% *; sway Area ≈ –35% *
Pietrangelo et al. 2009 [11]	Ageing	9	300 Hz; N.R.	15 min; 1–3 times a week for 12 weeks	Quadriceps/No	MVC	Immediately after treatment ending; 16 weeks	MVC ≈ +51% *
Bakhtiary et al., 2011 [31]	Limited hamstring extendibility	30	50 Hz; N.R.	20–60 sec; 3 times a day, 3 times a week for 8 weeks	Hamstring/no	Passive knee extension	Immediately after treatment ending	Knee extension +46% *
Celletti et al., 2011 [12]	Joint hypermobility syndrome	15	100 Hz; 0.2–0.5 mm	10 min; 3 times a day for 3 consecutive days	Quadriceps/Yes	Berg balance scale	10 and 40 days	Berg balance +27% *
Zaho et al., 2011 [13]	Immobilisation	30	100 Hz; 0,3 mm	1 min; 48 times a day for 2 weeks	Soleus/No	V-wave/M-wave	Immediately after treatment ending	Soleus V/M did not change in treated individuals. Untreated showed—30.78% **
Brunetti et al., 2012 [29]	Volleyball players	18	100 Hz; 0.2–0.5 mm	10 min; 3 times a day for 3 consecutive days	Quadriceps/Yes	Explosive and reactive leg power	24 h; 240 days	Treated group explosive leg power +26% **, reactive power +13% **; control group explosive leg power +11% *, reactive

Study	Origin of the Deficit	Sbjts	FV Frequency & Amplitude	Single Application Duration & Repetition	Muscle Body Part Treated/Muscle Contraction	Tests	1st Test and Last Test	Maximal After-Effect
								power +7.8% *
Tankisheva et al., 2015 [16]	Ageing	50	30–45 Hz; N.R.	30–60 sec; 4–8 times a day for 26 weeks	Quadriceps, Gluteus maximum and medium/No	MVC	Immediately after treatment ending	Quadriceps MVC +13.84% *
Rabini et al., 2015 [18]	Osteoarthritis	50	100 Hz; 0.2–0.5 mm	10 min; 3 times a day for 3 consecutive days	Quadriceps/Yes	WOMAC, SPPB. POMA	3 and 6 months	WOMAC −30% **; SPPB +45% **; POMA +31% **
Celletti et al., 2015 [14]	Ageing	350	100 Hz; 0.2–0.5 mm	10 min; 3 times a day for 3 consecutive days	Quadriceps/Yes	POMA test	1; 6 months	59% of the tested individuals reached the full POMA score **
Brunetti et al., 2015 [30]	Ageing	60	100 Hz; 0.2–0.5 mm	10 min; 3 times a day for 3 consecutive days	Quadriceps/Yes	Stability (cop area, velocity); vertical jump height; muscle power	1; 12 months	Sway −35% **; Vertical Jump + 40% **; Power + 40% **
Ribot-Ciscar et al., 2015 [17]	facio-scapulo-humeral muscular dystrophy	9	80 Hz; 0.5 mm	50 min; A total of 7 sessions, 1 every 4 days	Biceps brachialis; triceps brachialis; pectoralis major/No	Pain analogue visual scale; voluntarily shoulder abduction and flexion maximum amplitudes; MVC	Immediately after treatment ending	Pain analog visual scale, no significant changes; voluntarily shoulder abduction and flexion +20% *; MVC +41% *
Paoloni et al., 2015 [15]	Foot drop	44	120 Hz; 0,001 mm	30 min; 3 times a week, for 12 weeks	Tibialis anterior, peroneus longus/N.R.	Gait analysis	1 month	Improvements in ankle dorsiflexion,
Pazzaglia et al., 2016 [19]	Charcot-Marie-Tooth 1A disease	14	100 Hz; 0.2–0.5 mm	10 min; 3 times a day for 3	Quadriceps/Yes	Berg Balance scale; Dynamic gait index; 6-min	1 week; 1 month	Berg Balance scale +8% *; Dynamic gait index +15% *;

Study	Origin of the Deficit	Sbjts	FV Frequency & Amplitude	Single Application Duration & Repetition	Muscle Body Part Treated/Muscle Contraction	Tests	1st Test and Last Test	Maximal After-Effect
				consecutive days		walking test; Muscular strength of lower limbs; Body balance; SF-36;		=6-min walking test; =Muscular strength of lower limbs; ↑Body balance (Sway path * and velocity *); =SF-36;
Saggini et al., 2017 [21]	Ageing	30	300 Hz; N.R.	15 min; 2 times a week, for 6 months	Trapezius, triceps brachii, latissimus dorsi, rectus abdominis, gluteus maximus, rectus femoris, biceps femoris, and tibialis anterior/N.R.	Hand grip; knee extensores isokinetic strength; POMA test; ECOS-16 questionaire	Immediately after treatment ending	Grip +11% *; Isokinetic strength of the knee extensor +6% *; Poma Test + 5% *; Ecos-16 −17% *
Celletti et al., 2017 [20]	postmastectomy recovery	14	100 Hz; 0.2–0.5 mm	10 min; 3 times a day for 3 consecutive days	Pectoralis minor and the biceps brachi/Yes	DASH; questionnaire, Body Image Scale, McGill pain questionnaire, Constant Scale, and Short Form 36 questionnaire.	Immediately after treatment ending	DASH scale −28% *; Constant scale +14% *; theMcGill pain questionnaire −23% *; ↑Short Form 36 questionnaire (=physical mental score)
Benedetti et al., 2017 [22]	Ageing	30	150 Hz; N.R.	20 min; Once a day through five consecutive days, for 2 consecutive weeks	Rectus femoris, vastus medialis, and vastus lateralis	WOMAC; VAS; STAIR CLIMBING; TUG	48 h	WOMAC −20% **; VAS −49% **; STAIR CLIMBING −13% **; TUG −11% **
Souron et al., 2018 [23]	Ageing	17	100 Hz; 1 mm	1 h; 3 times a week, for 4 weeks	Rectus femoris/No	MVC, Vertical jump performance	Immediately after treatment ending	MVC ≈ +11% *; Maximal jump heights SJ ≈ +15.2% *, CMJ ≈ +6.5% *

…eness in …[12][14][15][17][18] [19][20][21][22][23][24] … [10][19][24][26][27][28][29][30] …ses, the … [12][14][18][20][21][22] … attention … [32] … training …y. In this case, the significant reduction in drooling was attributed, albeit with indirect evidence, to an improvement in swallowing, a highly coordinated motor task. Finally, one study specifically tested the effectiveness of the proprioceptive stimulation protocol on the training of volleyball players after the seasonal rest break [29]. Their explosive and reactive leg power was assessed at the beginning of the seasonal training and up to 240 days later. Although the athletes followed the same training, the stimulated group showed a much greater improvement than the control group. Interestingly, only 24 h after the end of treatment, the treated athletes showed significant and greater results than their colleagues 240 days later. This finding, discussed later, suggests a prominent role of proprioceptive drive in determining motor efficacy.

Study	Origin of the Deficit	Sbjts	FV Frequency & Amplitude	Single Application Duration & Repetition	Muscle Body Part Treated/Muscle Contraction	Tests	1st Test and Last Test	Maximal After-Effect
Iodice et al., 2019 [25]	Athletes' effects of eccentric exercise	30	120 Hz; 1,2 mm	15 min; once	Vastus intermedius, rectus femoris, vastus lateralis, vastus medialis, gluteus maximus, biceps femoris, adductor longus and magnus	isokinetic evaluation, stabilometric test, perceived soreness evaluation	48 h	MVC ≈ +13% **
Attanasio et al., 2020 [24]	Ageing	30	100 Hz; 0.2–0.5 mm	10 min; 3 times a day for 3 consecutive days	Quadriceps/Yes	Body balance, POMA test, TUG test	1 week	Sway ≈ −27% *; POMA test ≈ +20% **; TUG: rotation speed ≈ +8% **; duration ≈−19% *, standing up ≈ −13% **
Rippetoe et al., 2020 [26]	Diabetic Peripheral Neuropathy	23	120 Hz; 1.2 mm	10 min; 3 times a week, for 4 weeks	Tibialis anterior, quadriceps, and gastrocnemius/No	Gait Analysis	Immediately after treatment ending	↑Gait speed *, ↑cadence *, ↑stride time *, ↑left and right stance time *, ↑duration of double limb support *, ↑left and right knee flexor moments*
Coulandre et al., 2021 [27]	ACL reconstruction	30	100 Hz; 1 mm	1 h; only once	Quadriceps/No	MVC Rof force development	Immediately after treatment ending	Force decrease in vibrated subject −50% then unvibrated participants

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