Author Year; Country Score Research Design Total Sample Size	Methods	Outcome
Craven et. al 2017 Canada PEDro = RCT Level 1 N=34	**Population:** 34 participants (26 men, 8 women) with chronic traumatic SCI; C2-T12; age: 55 years; TPI: 5 years; 13 AIS C, 20 AIS D. **Outcome Measures:** OC was measured with radioimmunoassay, CTX with electrochemiluminescence immunoassay Roche Diagnostics GmbH and Serum sclerostin was measured by BIOMEDICA sclerostin ELISA. All markers were assessed at baseline, and 4 months. aBMD of total hip, distal femur and proximal tibia were assessed by DXA (4500A, Hologic Inc., Waltham, MA, USA). PQCT scan measured total vBMD, cortical vBMD, trabecular vBMD, cortical thickness (CoTh), strength-strain index and polar moment of inertia, at sites 4% and 38% of total tibia length **Treatment:** 45 min, 3x/week, 4 months. Control group (CONV): aerobic (20-25 min, 3-5 Borg; arm or leg bicycling, walking in parallel bars or on the treadmill) and resistance (2–3	1. Participants in the FES-walking arm had a decrease in CTX (0.26 – 0.24 ng/ml, p = 0.05) and a significant increase in OC (16.7 – 17.8, p = 0.02) at intervention completion. 2. No significant biomarker change was observed in CONV arm at intervention completion. 3. No within or between-group differences were observed in sclerostin at intervention completion 4. No between-group differences were observed in aBMD of total hip, distal femur, or proximal tibia at any point 5. No between-group differences were observed in vBMD of the tibia 4% and 38% site or pQCT bone architecture outcomes at any point

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	sets of 12–15 repetitions maximum resistance for muscles capable of voluntary contraction) exercise program. FES-walking with bodyweight support group: open-loop FES (8–125 mA, 250–300 μs pulse duration, 20–50 Hz) over the quadriceps, hamstrings, tibialis anterior and gastrocnemius while walking with body weight support.	
Johnston et al. 2016 USA PEDro = 5 RCT Level 1 N=17	**Population:** 17 participants (14 men, 3 women); age: 42 ± 12 years; TPI: 12 ± 10 years; 8 cervical, 9 thoracic; AIS-A/B. **Treatment:** FES-cycling 1h per session, 3 times per week for 6 months Low cadence group: n=8 at 20 RPM High cadence group: n=7 at 50 RPM n=2 withdrew due to personal reasons **Outcome Measures:** Trabecular bone micro-architecture (apparent trabecular number; apparent trabecular separation; apparent bone volume to total volume), BMD by DXA, serum bone-specific ALP, urine NTX, other biochemical markers & muscle volume	1. No significant between-group or within-group differences for bone micro-architecture measures 2. Large effect sizes seen for distal femur apparent trabecular number, apparent trabecular separation and a moderate effect size were seen for apparent bone volume to total volume 3. Significantly greater decrease between-groups in bone ALP in low cadence group 4. Low cadence group decreased bone ALP by 15.5%, whereas high cadence group increased by 10.7%

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		5. Significant within-group decrease in NTX in low cadence group 6. Low cadence group decreased NTX by 34%, whereas high cadence group decreased by 10%
Hammond et. al 2014 USA Cross-sectional Level 5 N=364	**Population:** 364 participants with SCI; age 39.8 ± 16.1 years; 276 traumatic, 88 nontraumatic; 79 ambulatory; 202 FES users; TPI: 6.9 (range: 1-8) years; 178 AIS A and B, 184 AIS C and D. **Treatment:** N/A **Outcome Measures:** The prevalence of osteoporosis, defined as having ≥1 region of interest on a DXA (Hologic Discovery equipment and software) examination with a T score ≤2.5, based on FES-cycling usage (RT 300 SL). General FES-cycling parameters: maximal intensity of 140 mA, 500 µs pulse duration, 30 to 40 Hz frequency, with a target goal of 50 revolutions per minute, 30-60 min/session). Other data recorded: age, sex, level and severity of injury as per the American Spinal Injury Association (ASIA) Impairment Scale (AIS), TPI,	1. Prevalence of osteoporosis was 34.9% (n=127). Osteopenia (defined as a T score between >-1 and -2.4) was present in 46.7% (n=170) of participants, and BMD was normative in only 18.4% (n=67). 2. FES-cycling usage [mean (confidence interval - CI)]: 20.2 (1.0-24.0) weeks, 2.3 (1.0-3.0) sessions per week, average distance of 8.1 (4.7-10.5) km, average energy per hour 61,412.8 kJ/h, average stimulation level (% range 0-100) 83.2 (76.4-99.0) and average charge level 28.8 (17.5-34.7) µC. 3. FES-cycling was associated with 31.2% prevalence of osteoporosis compared with 39.5% among persons not using FES. FES use was associated with 42% decreased odds (Odds Ratio/OR = 0.58; 95% confidence interval (CI) =

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	ambulatory status, FES usage, daily calcium and vitamin D intake, and anticonvulsant drug use.	0.35-0.99) of osteoporosis after adjusting for sex, age, BMI, type and duration of injury, Lower Extremity Motor Scores (LEMS), ambulation, previous bone fractures, and use of calcium, vitamin D and anticonvulsant. 4. Healthy BMI (from 25-40) showed 58% decreased odds of osteoporosis in adjusted analysis (OR = 0.42; 95% CI = 0.24-0.73) 5. Duration of injury >1 year was associated with a 3-fold increase in odds of osteoporosis compared with individuals with <1 year. 6. Type and severity of injury, calcium and vitamin D intake, use of anticonvulsant therapy, and previous bone fractures were not associated with the likelihood of having osteoporosis.
Ashe et al. 2010 Canada Case Series Level 4 N= 3	**Population**: 3 women with traumatic chronic motor SCI; TPI: >1 year; complete n=2, incomplete n=1; ages: 29, 19, 51 years. **Treatment:** Computer-controlled leg FES-cycling training for 6 months, 3	1. All three participants had a percentage change in BMD ranging between 1-16% 2. There was maintenance of cortical bone density in all 3 participants at 50% site ranging from 0.51-1.24%

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	times a week. Including habituation and training phases **Outcome Measures:** Pre-post BMD (g/cm^2) using DXA (lower extremity); pre-post differences in bone health i.e. total content (g/mm) and density (mg/cm^3) using pQCT at midshaft (50%) and distal (5%) sites of tibia	3. At distal site, all three participants responded differently. Increase in BMD in both legs n=1, increase in right leg n =1, increase in left leg n=1
Frotzler et al. 2009 Switzerland/UK Pre-Post Level 4 N = 5	**Population:** 4 men and 1 woman with traumatic SCI; age: 38.6 ± 8.1 years; T4-T7; ASIA grade A; TPI: 11.4 years (range 3.6–19.8); who showed significant effects on bone parameters due to high-volume FES-cycling **Methods:** Follow-up on Frotzler et al. 2008: 4 participants stopped FES-cycling and 1 had reduced training (two-three 30-minute sessions/week) **Outcome Measures:** Trabecular and total BMD and BMC by pQCT.	**Participants who stopped training:** *Distal femur:* 73%±13.4% of total gain in BMDtrab; 63.8%±8.0% in BMDtot, and 59.4%±3.9% in BMC were preserved after 12 months of detraining **Participant with reduced training:** 96.2% of total gain in BMDtot and 95% of gain in BMDtrab in the distal femur were preserved
Frotzler et al. 2008 Switzerland/UK Pre-Post Level 4 N=11	**Population:** 11 participants (2 women, 9 men) with traumatic SCI; T3-T12; age: 41.9 ± 7.5 years; TPI: 11.0 ± 7.1 years; AIS A. **Treatment:** FES-cycling, five 60-min sessions per week for 12 months	**Distal Femur:** 1. Trabecular BMD increased by 14.4±21.1% 2. Total BMD increased by 7.0±10.8% 3. Total bone cross-sectional area increased by 1.2±1.5% **Femoral Shaft:**

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	Outcome Measures: Femur and tibia: trabecular, cortical, and total BMD, BMC and total bone cross-sectional area by pQCT.	1. Cortical BMD decreased by 0.4±0.4% 2. BMC decreased by 1.8±3.0% **Tibia:** No significant changes in bone parameters.
Chen et al. 2005 Taiwan Pre-post Level 4 N=30	**Population:** 15 men, age: 28.67 (range: 23 ± 37) years; TPI: 9.3 ± 3.9 years; complete, C6-T8. 15 matched non-disabled controls. **Treatment:** FES-cycling. Participants performed FES-cycling exercises with minimal resistance for 30 minutes/day, 5 days/week for 6 months. Follow-up 6 months after intervention. **Outcome measures:** BMD of the hip. Femoral neck, distal femur and proximal tibia by DXA	1. At baseline, participants' BMD at the femoral neck, distal femur and proximal tibia was lower than controls. 2. After 6 months, BMD of the distal femur and proximal tibia increased significantly ($p<0.05$). BMD in the distal femur, proximal tibia, and heel decreased significantly after 6 months without intervention ($p<0.05$). The BMD of the femoral neck decreased progressively throughout the treatment ($p>0.05$).
Mohr et al. 1997 Denmark Pre-post Level 4 N=10	**Population:** 10 men and women; age: 27-45 years, injuries either C6 or T2, no controls. **Treatment:** FES. Sequential electrical stimulation of the quadriceps, hamstrings, and gluteal muscle groups to generate a cycling motion for 30 min, 3x/week for 6 months, followed by 1x/week for 6 months.	1. After 12 months of training, there was a significant 10% increase in proximal tibia BMD ($p < 0.05$) but no change in the lumbar spine or femoral neck. 2. After 6 months of reduced training, BMD for the proximal tibia returned to baseline. 3. Blood and urine markers were within normal limits

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	Outcome measures: Lumbar spine, femoral neck, distal femur, proximal tibia and BMD by DXA and bone turnover markers (osteocalcin and deoxypyridinoline).	at baseline and there were no significant changes with FES.
BeDell et al. 1996 USA Pre-post Level 4 N=12	**Population:** 12 men; age: 34 ± 6 years (range: 23-46); complete traumatic injuries between C5-T12; TPI: >2 years; no controls. **Treatment**: FES-cycling. Participants participated in a 3-phase training program. Phase 1: quadriceps strengthening through NMES. Phase 2: FES-cycling progression until 30 min continuously. Phase 3a: 24x 30-mins continuous FES-cycling sessions performed 3x/week. Phase 3b: An extra 24x 30-min FES-cycling sessions adding simultaneous arm ergometry (8 participants only). **Outcome measure:** lumbar spine and hip BMD by DPA	1. At baseline, SCI participants were not significantly different from age-matched non-disabled ambulatory men for lumbar-spine BMD. However, BMD was significantly lower for participants at the hip ($p<0.025$) for bilateral trochanters, Wards triangles, and femoral necks. 2. Only the L2-L4 values demonstrated a trend ($p=0.056$) for a small positive effect from training. Further training (Phase 3b) did not demonstrate further increase in BMD at any site.
Hangartner et al. 1994 USA Pre-post Level 4 N=15	**Population:** 15 participants; age: 17-46 years; complete and incomplete injury between C5-T10; no controls. **Treatment:** NMES and FES-cycling.	1. Participants in the exercise groups continued to lose bone at the distal and proximal end of the tibia, but it was less than expected from the regression lines.

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	1. NMES knee extension exercises (n=3); 2. FES-cycling (n=9); or 3. both (n=3). Sessions were 3x/week for 12 weeks except Group 3 had 24 weeks. **Outcome measures:** tibia BMD specify site (proximal and distal) via CT	
Leeds et al. 1990 USA Pre-post Level 4 N=6	**Population:** 6 men; ages 18-27; C4-C6; traumatic tetraplegia; no controls. **Treatment:** NMES and FES cycle ergometry. 1-month quads strengthening exercise (NMES), followed by 6 months of FES-cycling. Knee extension sessions were 45 lifts/leg 3x/week for 1month. FES-cycling sessions were 3X/week up to 30 mins for 6 months. **Outcome measures:** Hip BMD by DXA	1. The BMD of the proximal femurs were below normal before commencing exercise intervention (compared with matched non-disabled individuals). 2. After 7 months of exercise training, there was no significant difference in BMD for any of proximal femur sites
Pacy et al. 1988 UK Pre-post Level 4 N=4	**Population:** 4 men; age: 20-35 years; paraplegia; no controls. **Treatment:** NMES and FES-cycling. Part 1 was NMES of quads strengthening with ↑ load ranging from 1.4-11.4 kg bilateral for 15 mins for 5x/week (10 weeks). Part 2 was FES-cycling at 50 rpm with resistance (0-18.75 W). Performed for 15 mins, 5x/week (32 weeks).	1. No significant change in lumbar, femoral shaft, or distal tibia trabecular BMD after the intervention.

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	Outcome measures: Lumbar spine, hip, and distal tibia BMD by CT.	

* All data expressed as mean±SD, unless expressed otherwise.