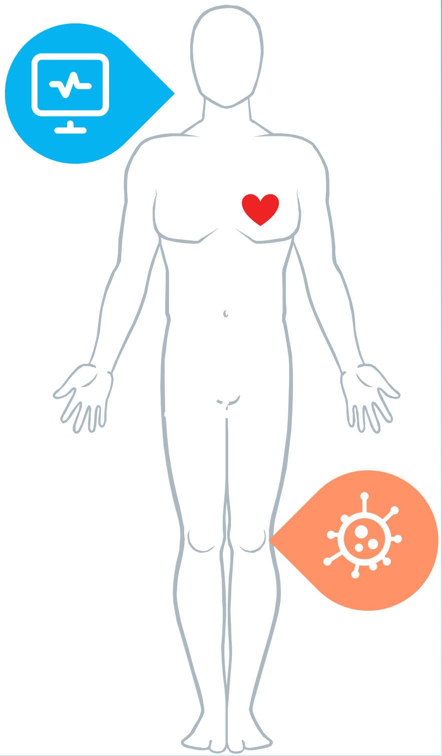
ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
Εθνικόν και Καποδιστριακόν Πανεπιστήμιον Αθηνών

Σχέση Άθλησης και Οστεοπόρωσης



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ΙΑΣΩ
Για ό,τι πιο πολύτιμο έχεις.

Δομή Ομιλίας

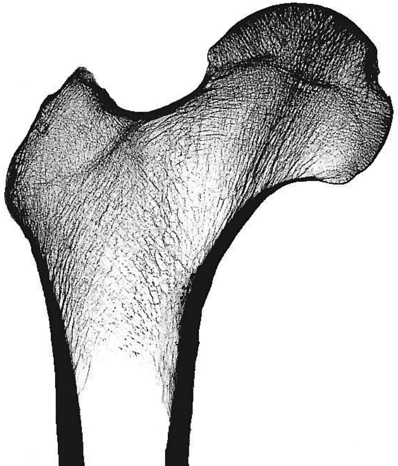
1. Γενικές αρχές προσαρμογής του οστού στη φυσική δραστηριότητα

2. Βιβλιογραφική ανασκόπηση 2020-2022

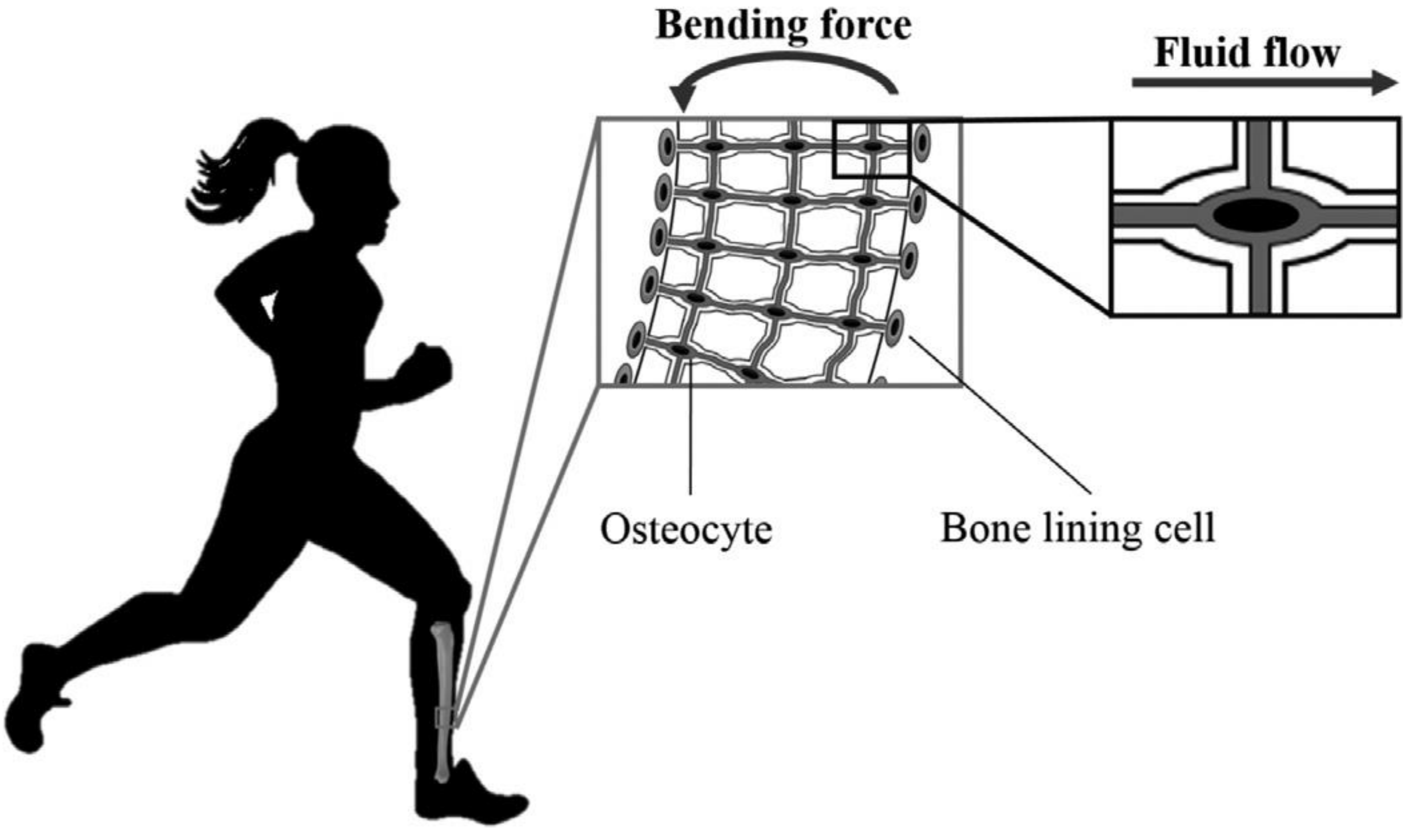
3. Συνταγογράφηση άσκησης στην οστεοπόρωση

- **Bones** adapt to their mechanical environment

- **Size, mass, shape and strength** are regulated according to the habitual level of strain experienced



Mechanotransduction



Bone Vol. 23, No. 5
November 1998:399–407

ELSEVIER

ORIGINAL ARTICLES

Three Rules for Bone Adaptation to Mechanical Stimuli

C. H. TURNER

Biomechanics and Biomaterials Research Center and Indiana University School of Medicine, IUPUI, Indianapolis, IN, USA

The key loading characteristics to stimulate an adaptive skeletal response

1. Dynamic intermittent rather than static loads

Lanyon L.E., Rubin C.T. Static vs dynamic loads as an influence on bone remodelling. J Biomech. 1984;17(12):897–905

2. Loads that are high in magnitude and applied rapidly

Rubin C.T., Lanyon L.E. Regulation of bone mass by mechanical strain magnitude. Calcif Tissue Int. 1985;37(4):411–417

O'Connor J.A., Lanyon L.E., MacFie H. The influence of strain rate on adaptive bone remodelling. J Biomech. 1982;15(10):767–781

3. Loads that are applied in unusual or diverse loading directions or patterns

Lanyon L.E., Goodship A.E., Pye C.J., MacFie J.H. Mechanically adaptive bone remodelling. J Biomech. 1982;15(3):141–154.

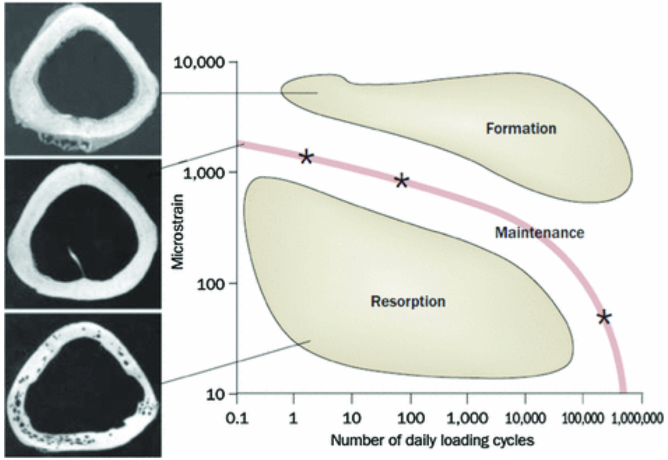
Rubin C.T., Lanyon L.E. Regulation of bone formation by applied dynamic loads. J Bone Joint Surg Am. 1984;66(3):397–402.

4. if an adequate load intensity is achieved, relatively few loading cycles (repetitions),

Umemura Y., Ishiko T., Yamauchi T., Kurono M., Mashiko S. Five jumps per day increase bone mass and breaking force in rats. J Bone Miner Res. 1997;12(9):1480–1485.

- Bone cells **desensitize** to repetitive loading

- The capacity of bone to respond to **continual loading** diminishes over time or with increasing repetitions



J Musculoskelet Neuronal Interact 2006; 6(2):162-166

Perspective Article

Hylonome

Can exercise prevent osteoporosis?

J. Rittweger

Institute for Biophysical and Clinical Research into Human Movement, MMU at Cheshire, Alsager, Cheshire, UK

Exercise

- Maintains bone strength
- Reduces loss of bone mineral density (BMD)
- Promotes bone strength

- Beck BR et al. 2017 Journal of Science & Medicine in Sport 20, 438–445
- Howe TE et al. 2011 Cochrane Database of Systematic Reviews doi: 10.1002/14651858.CD000333.pub2
- Kohrt WM et al. 2004 Medicine & Science in Sports & Exercise 36, 1985–1996

- **Moderate impact and high intensity muscle resistance** exercise undertaken by older women, leads to improvements in BMD

- Watson SL et al. 2017, Journal of Bone & Mineral Research 33, 211–220

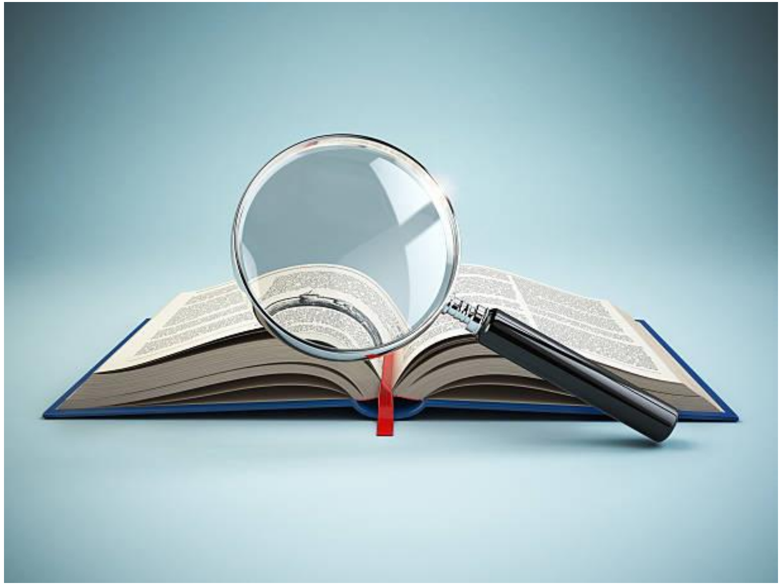
- **Not all exercises** have the same effect on the bone
- **Swimming** and **cycling** appear to have little benefit for lower limb bone health

- **Low-impact activities** such as walking are beneficial to general health

- They **do not** improve bone density

Literature Review - 1

- RCT's



Osteoporosis International
https://doi.org/10.1007/s00198-019-05256-4

Osteoporos Int. 2020 Jun;31(6):1069-1078

ORIGINAL ARTICLE

1

Effects of a resistance and balance exercise programme on physical fitness, health-related quality of life and fear of falling in older women with osteoporosis and vertebral fracture: a randomized controlled trial

B. Stanghelle[1] · H. Bentzen[2] · L. Giangregorio[3] · A.H. Pripp[4] · D. Skelton[5] · A. Bergland[6]

- Single blinded RCT
- **149 women 65+ years**
- With **osteoporosis and vertebral fracture**
- **Study Group**:12-week multicomponent exercise programme ---- **Control group**: Received usual care
- **Primary outcome:** habitual walking speed
- **Secondary outcomes:**
- physical fitness (Senior Fitness Test, Functional Reach and Four Square Step Test)
- health-related quality of life
- fear of falling

Osteoporosis International
https://doi.org/10.1007/s00198-019-05256-4

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1

- **No SS difference** between the groups
  - on the primary outcome, walking speed (mean difference 0.04 m/s)
  - on health-related quality of life
- **SSD** between-group differences in favour of intervention were found on
  - FSST (dynamic balance, mean diff. - 0.80 s)
  - Arm curl (mean diff. 1.55)
  - 30-s STS (mean diff. 1.85)
  - Fear of falling (mean diff. -1.45)

CLINICAL TRIAL

JBMR

J Bone Miner Res. 2020 Sep;35(9):1634-1644.

2

Effects of High-Intensity Resistance Training on Osteopenia and Sarcopenia Parameters in Older Men with Osteosarcopenia—One-Year Results of the Randomized Controlled Franconian Osteopenia and Sarcopenia Trial (FrOST)

Wolfgang Kemmler,[1] Matthias Kohl,[2] Michael Fröhlich,[3] Franz Jakob,[4] Klaus Engelke,[1,5]
Simon von Stengel,[1] and Daniel Schoene[1]

- **Low-volume/high-intensity Dynamic resistance exercise (HIT-DRT)** on bone mineral density (BMD) and skeletal muscle mass index (SMI) in men with osteosarcopenia
- **43 sedentary community-dwelling older men (73-91 years)** with osteopenia/osteoporosis and SMI-based sarcopenia
- **Randomly assigned** to a HIT-RT exercise group (EG; n = 21) or a control group (CG; n = 22)
  - **HIT-RT:** progressive, periodized single-set DRT with high intensity, effort, and velocity 2X/ week
  - **Control Group:** maintained their lifestyle

CLINICAL TRIAL

JBMR

J Bone Miner Res. 2020 Sep;35(9):1634-1644.

Effects of High-Intensity Resistance Training on Osteopenia and Sarcopenia Parameters in Older Men with Osteosarcopenia—One-Year Results of the Randomized Controlled Franconian Osteopenia and Sarcopenia Trial (FrOST)

2

Wolfgang Kemmler,[1] Matthias Kohl,[2] Michael Fröhlich,[3] Franz Jakob,[4] Klaus Engelke,[1,5] Simon von Stengel,[1] and Daniel Schoene[1]

- Both groups were **supplemented** with whey protein, vitamin D, and calcium
- **Primary study endpoint:**
  - Lumbar spine (LS-BMD) QCT
- **Secondary study endpoints:**
  - SMI (DEXA)
  - BMD at the total hip
  - maximum isokinetic hip-/leg-extensor strength (leg press)

CLINICAL TRIAL

JBMR

J Bone Miner Res. 2020 Sep;35(9):1634-1644.

Effects of High-Intensity Resistance Training on Osteopenia and Sarcopenia Parameters in Older Men with Osteosarcopenia—One-Year Results of the Randomized Controlled Franconian Osteopenia and Sarcopenia Trial (FrOST)

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2

- **12 months** of exercise
  - **LS-BMD** was maintained in the EG and ↓ significantly in the CG
  - **SMI** ↑ significantly in the EG and ↓ significantly in the CG
  - **Total hip BMD** changes did not differ significantly between the groups
  - Changes in **maximum hip-/leg-extensor strength** were much more prominent ($p < 0.001$; SMD=1.92) in the EG

Osteoporosis International
https://doi.org/10.1007/s00198-020-05746-w

ORIGINAL ARTICLE

Osteoporos Int. 2021 May;32(5):883-891

High-Intensity Physical Activity with High Serum Vitamin D Levels is Associated with a Low Prevalence of Osteopenia and Osteoporosis: A Population-Based Study

3

C. Min[1,2] · D. M. Yoo[1] · J. H. Wee[3] · H.-J. Lee[3] · H. G. Choi[1,3]

- Korean National Health and Nutrition Examination Survey, data from 2008-2011
- 6868 individuals
- **Physical Activity** was classified as 'low', 'moderate', or 'high'
- **Serum 25(OH)D levels** were classified as 'low' or 'high'
- The combined PA and 25(OH)D groups were divided into **6 groups**
- **BMD** was classified as normal (T score ≥ -1), osteopenia (- 2.5 < T <-1) or osteoporosis (T ≤-2.5)
- **Crude and adjusted odds ratios** (AORs) with 95% CIs were calculated using multinomial logistic regression models

Osteoporosis International
https://doi.org/10.1007/s00198-020-05746-w

ORIGINAL ARTICLE

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High-Intensity Physical Activity with High Serum Vitamin D Levels is Associated with a Low Prevalence of Osteopenia and Osteoporosis: A Population-Based Study

C. Min[1,2] · D. M. Yoo[1] · J. H. Wee[3] · H.-J. Lee[3] · H. G. Choi[1,3]

Results:

- The **AORs** (95% CIs) for **osteopenia** were 0.64 (0.50-0.83) in the high PA with high 25(OH)D group and 0.69 (0.53-0.88) in the moderate PA with high 25(OH)D group
- The **AORs** (95% CIs) for **osteoporosis** were increased in the groups in ascending order as follows:
    - **high PA with high 25(OH)D** (0.40 [0.28-0.57]) < moderate PA with high 25(OH)D (0.47 [0.33-0.66]) < low PA with high 25(OH)D (0.59 [0.42-0.83]) < high PA with low 25(OH)D (0.70 [0.49-1.00]) < moderate PA with low 25(OH)D (0.76 [0.53-1.07]) < low PA with low 25(OH)D
- This result was **consistent in males** but not evident in females
- The combination of **high-intensity PA and high 25(OH)D levels is positively associated with high BMD**

Bone-loading exercises versus risedronate for the prevention of osteoporosis in postmenopausal women with low bone mass: a randomized controlled trial. Waltman et al.

Osteoporos Int. 2022 Feb;33(2):475-486

4

- **RCT**
- Changes in **BMD and bone turnover** in postmenopausal women with low bone mass
- **276 women** with low bone mass, within 6 years of menopause
- Treatment groups were 12 months of:
  (a) calcium and vitamin D supplements (CaD) (control)
  (b) risedronate + CaD
  (c) bone-loading exercises + CaD
- **BMD and serum markers for bone formation (Alkphase B) and resorption (Serum Ntx)** were analyzed at baseline, 6, and 12 months

Bone-loading exercises versus risedronate for the prevention of osteoporosis in postmenopausal women with low bone mass: a randomized controlled trial. Waltman et al.

Osteoporos Int. 2022 Feb;33(2):475-486

4

- **Results:**
- **BMD at the spine:**
- ↑ in the **risedronate** group compared to exercise ($p \leq .010$) or control groups ($p \leq .001$)

- **At 12 months:**
- **Changes in BMD** at the spine, hip, and femoral neck from baseline
  - **risedronate +1.9%,+0.9%, and +.09%**
  - exercise group women, +0.2%, +0.5%, and -0.4%
  - control group women, - 0.7%, +0.5%, and -0.5%

- **12-month changes in Alkphase B and Serum Ntx**
  - **risedronate - 20.3% and - 19.0%**
  - exercise, - 6.7% and - 7.0%
  - control, - 6.3% and - 9.0%

Bone-loading exercises versus risedronate for the prevention of osteoporosis in postmenopausal women with low bone mass: a randomized controlled trial. Waltman et al.

Osteoporos Int. 2022 Feb;33(2):475-486

4

- **Conclusion:**

- Postmenopausal women with low bone mass should obtain adequate **calcium and vitamin D and participate in bone-loading exercises**

- **Additional use of BPs** will increase BMD, especially at the spine

nutrients

MDPI

Nutrients 2020, 12, 2341

Article

Effects of High Intensity Dynamic Resistance Exercise and Whey Protein Supplements on Osteosarcopenia in Older Men with Low Bone and Muscle Mass. Final Results of the Randomized Controlled FrOST Study

Wolfgang Kemmler [1,*], Matthias Kohl [2], Franz Jakob [3], Klaus Engelke [1,4] and Simon von Stengel [1]

5

- The effect of **high intensity dynamic resistance exercise (HIT-DRT**) and whey protein supplementation (WPS) on BMD and sarcopenia parameters in osteosarcopenic men

- **Men > 72 years** with osteosarcopenia (n = 43) were randomly assigned to:
  - HIT-RT (HIT-RT: n = 21)
  - Non-training control group (n = 22)

nutrients

MDPI

Nutrients 2020, 12, 2341

Article

Effects of High Intensity Dynamic Resistance Exercise and Whey Protein Supplements on Osteosarcopenia in Older Men with Low Bone and Muscle Mass. Final Results of the Randomized Controlled FrOST Study

Wolfgang Kemmler [1,*], Matthias Kohl [2], Franz Jakob [3], Klaus Engelke [1,4] and Simon von Stengel [1]

5

- **Supervised HIT-RT 2X/week** was applied **for 18 months**, while the control group maintained their habitual lifestyle

- **Total protein intake** amounted to 1.5–1.6 (HIT-RT) and 1.2 g/kg/body mass/d (control)
- Both groups were supplied with calcium and vitamin D

- **Primary study outcomes:**
  - BMD
  - sarcopenia Z-score

nutrients

MDPI

5

Article

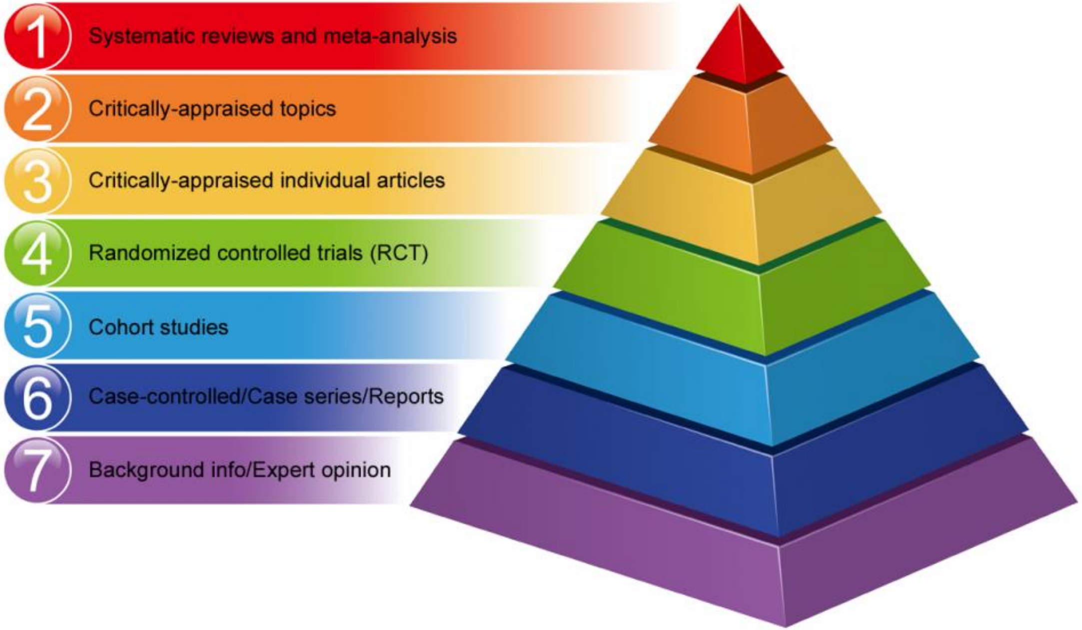
Effects of High Intensity Dynamic Resistance Exercise and Whey Protein Supplements on Osteosarcopenia in Older Men with Low Bone and Muscle Mass. Final Results of the Randomized Controlled FrOST Study

Wolfgang Kemmler [1,*], Matthias Kohl [2], Franz Jakob [3], Klaus Engelke [1,4] and Simon von Stengel [1]

- **Significant positive effects for**:
  - Sarcopenia Z-score (standardized mean difference, SMD: 1.40)
  - BMD at lumbar spine (SMD: 0.72) and total hip (SMD: 0.72)
- Effect sizes for skeletal **muscle mass changes** were very pronounced (1.97, $p < 0.001$)
- Effects for **functional sarcopenia parameters** were
  - handgrip strength-moderate (0.87, $p = 0.008$)
  - gait velocity-low (0.39, $p = 0.209$)

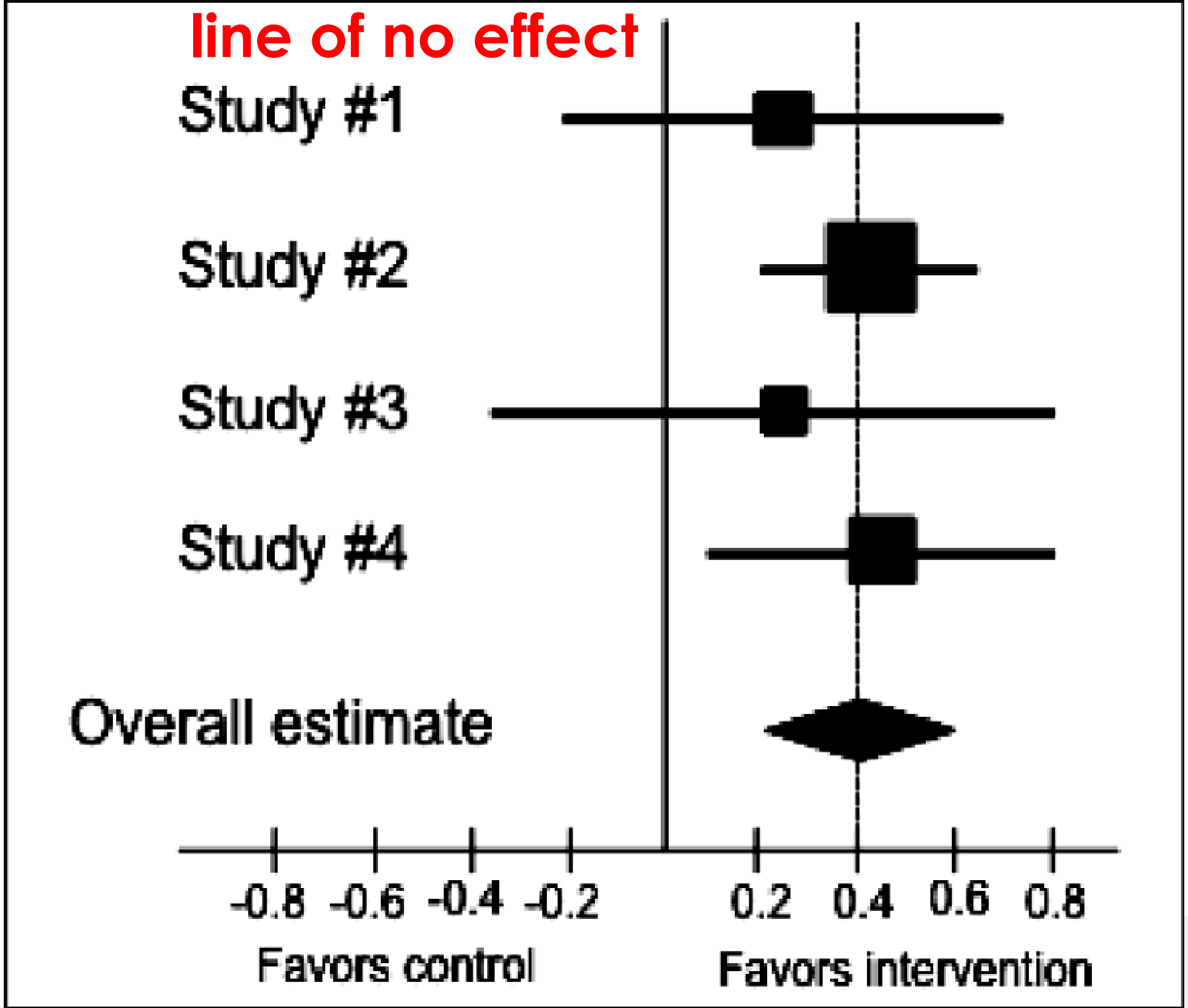
Literature Review - 2

- Metaanalyses



Λόγος σχετικών Πιθανοτήτων-Odds Ratio 95% CI

- OR=1 καμία επίδραση παράγοντα
- OR>1 βλαπτική επίδραση
- OR<1 προστατευτική επίδραση



Calcified Tissue International (2020) 107:409–439
https://doi.org/10.1007/s00223-020-00744-w

REVIEW ARTICLE

1

Effects of Different Types of Exercise on Bone Mineral Density in Postmenopausal Women: A Systematic Review and Meta-analysis

Wolfgang Kemmler[1] · Mahdieh Shojaa[1] · Matthias Kohl[2] · Simon von Stengel[1]

- The effect of **different types of exercise on areal BMD** in postmenopausal women
- Included: (a) controlled trials, (b) with at least one exercise and one control group, (c) intervention ≥ 6 months, (d) BMD assessments at lumbar spine (LS), femoral neck (FN) or total hip (TH), (e) in postmenopausal women

- **84 eligible exercise groups** were classified into
  - **(a)** weight bearing (WB, n = 30) exercise
  - **(b)** (dynamic) resistance exercise (DRT, n = 18)
  - **(c)** mixed WB&DRT interventions (n = 36)

- **Outcome measures:** standardized mean differences for BMD-changes at LS, FN and TH

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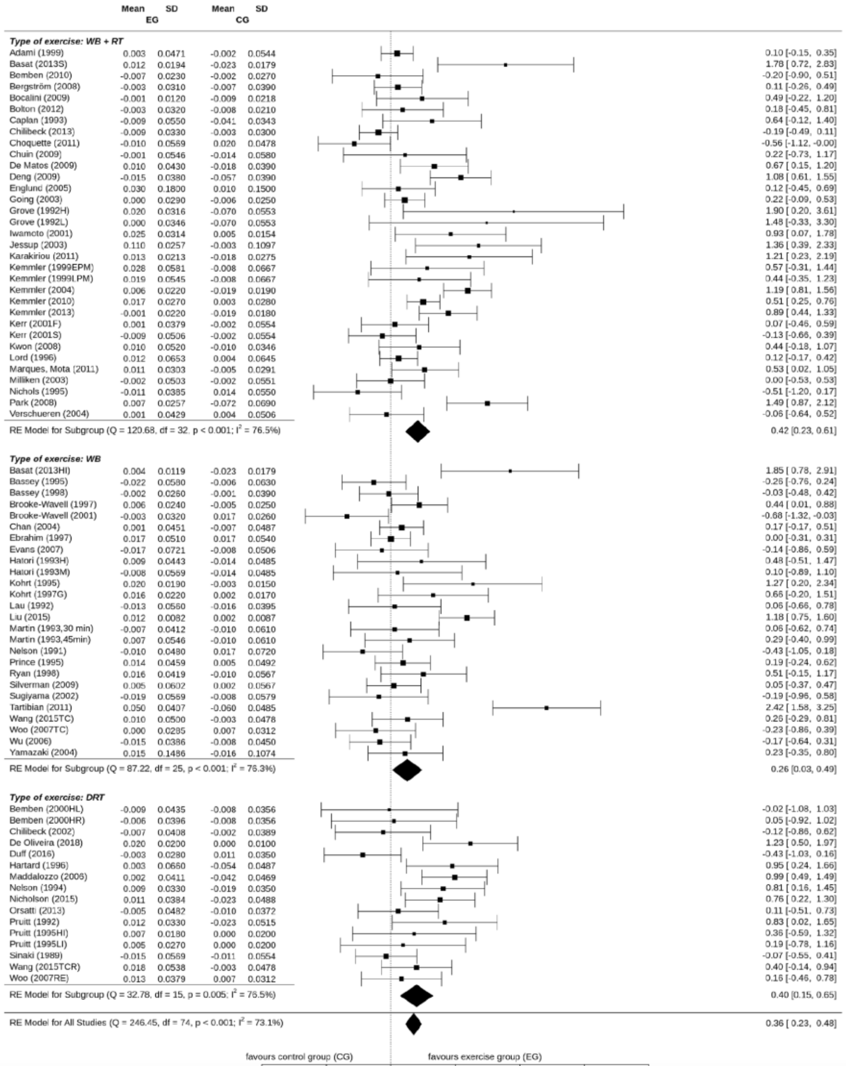
Wolfgang Kemmler[1] · Mahdieh Shojaa[1] · Matthias Kohl[2] · Simon von Stengel[1]

- **All types of exercise significantly affect BMD at LS, FN and TH**
- **SMD for LS**
  0.40 (95% CI 0.15–0.65) for DRT
  0.26 (0.03–0.49) for WB
  0.42 (0.23–0.61) for WB&DRT
- **SMD for FN**
  0.27 (0.09–0.45) for DRT
  0.37 (0.12–0.62) for WB
  0.35 (0.19–0.51) for WB&DRT
- **SMD for TH changes**
  0.51 (0.28–0.74) for DRT
  0.40 (0.21–0.58) for WB
  0.34 (0.14–0.53) for WB&DRT



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REVIEW ARTICLE

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Wolfgang Kemmler[1] · Mahdieh Shojaa[1] · Matthias Kohl[2] · Simon von Stengel[1]

2

- **Favourable effect of exercise on BMD** largely independent of the type of exercise

Osteoporosis International
https://doi.org/10.1007/s00198-022-06357-3

REVIEW

2

Effects of non-supervised exercise interventions on bone mineral density in adult women: a systematic review and meta-analysis

H. Sanchez-Trigo[1] · J. Rittweger[2,3] · B. Sañudo[1]

Received: 24 May 2021 / Accepted: 16 February 2022

- The effects of **non-supervised osteoporosis prevention programs** on BMD

- **Non-supervised exercise** ↑ femoral neck and lumbar spine bone mineral density in adult women.
  Thus, it might be effective for preventing or treating osteoporosis or osteopenia in this population

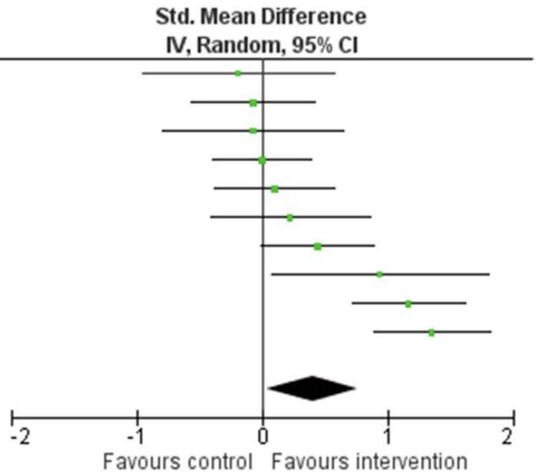
- **Included:** (a) prospective RCTs comparing at least one exercise group vs. a control group with sedentary lifestyle or sham exercises; (b) baseline and follow-up BMD values, or BMD changes from baseline, at any skeletal site; (c) women over 30 years old; and (d) non-supervised exercise programs only

- **Subgroup analyses** for menopausal status, intervention duration, type of exercise, and osteopenia/osteoporosis status

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
SugiyamaPOSM 2002	-0.019	0.057	13	-0.008	0.058	13	8.3%	-0.19 [-0.96, 0.59]
Sinaki 1989	-0.015	0.057	34	-0.011	0.055	31	10.7%	-0.07 [-0.56, 0.42]
SugiyamaPREM 2002	-0.012	0.025	14	-0.01	0.031	16	8.8%	-0.07 [-0.79, 0.65]
Ebrahim 1997	0.017	0.051	49	0.017	0.054	48	11.4%	0.00 [-0.40, 0.40]
Niu 2010	0.008	0.059	34	0.002	0.058	33	10.8%	0.10 [-0.38, 0.58]
Yamazaki 2004	0.015	0.149	27	-0.016	0.107	15	9.5%	0.22 [-0.41, 0.86]
Brooke-Wavell 1997	0.006	0.024	38	-0.005	0.025	40	11.0%	0.44 [-0.01, 0.89]
Iwamoto 2001	0.025	0.031	8	0.005	0.015	20	7.6%	0.94 [0.08, 1.81]
Liu 2015	0.012	0.008	48	0.002	0.009	42	11.0%	1.17 [0.72, 1.62]
Greenway 2015	0.03	0.046	36	-0.032	0.045	55	10.9%	1.35 [0.89, 1.82]
Total (95% CI)			**301**			**313**	**100.0%**	**0.40 [0.03, 0.77]**

Heterogeneity: $Tau^2 = 0.26$; $Chi^2 = 41.93$, df = 9 ($P < 0.00001$); $I^2 = 79\%$

Test for overall effect: $Z = 2.14$ ($P = 0.03$)



- **Results:**
- **10 studies** were included (n=668)
- **Unsupervised exercise** had beneficial effects on lumbar spine BMD (SMD= 0.40, 95% CI 0.03–0.77), and femoral neck BMD (SMD = 0.51, 95% CI: 0.16–0.85)
- **Unsupervised exercise increased LS** (SMD=0.73, 95% CI 0.13–1.33) **and FN BMD** (SMD=0.85, 95% CI: 0.33–1.37) in women with osteopenia/osteoporosis, but not in healthy counterparts

Osteoporosis International
https://doi.org/10.1007/s00198-022-06357-3

REVIEW

Effects of non-supervised exercise interventions on bone mineral density in adult women: a systematic review and meta-analysis

H. Sanchez-Trigo[1] · J. Rittweger[2,3] · B. Sañudo[1]

Received: 24 May 2021 / Accepted: 16 February 2022

Conclusions

- **Non-supervised exercise programs** improve BMD at FN and LS in adult women
- Interventions based on **DWBHF dynamic weight-bearing exercise high force** (e.g., jumping, plyometrics) might be **most effective** for improving FN BMD in adult women
- **Positive effects** of non-supervised exercise on BMD might be observed **in periods shorter than a year** and especially effective in women already diagnosed with osteopenia or osteoporosis
- Due to the **low number of trials** conducted to date, more RCTs prescribing non-supervised, osteogenic exercise are required in adult women
- More trials investigating the efficacy of **remote/assistive technologies** for delivering and monitoring non-supervised exercise interventions are also necessary

Review Article

The effect of different training frequency on bone mineral density in older adults. A comparative systematic review and meta-analysis

Bone 154 (2022) 116230

Anna-Lena Zitzmann[a,1], Mahdieh Shojaa[a,b,1], Stephanie Kast[a,1], Matthias Kohl[c,1], Simon von Stengel[a,1], Diana Borucki[d,1], Markus Gosch[e,1], Franz Jakob[f,1], Katharina Kerschan-Schindl[g,1], Bernd Kladny[h,1], Uwe Lange[i,1], Stefan Middeldorf[j,1], Stefan Peters[k,1], Daniel Schoene[a,1], Cornel Sieber[l,1], Friederike Thomasius[m,n,1], Michael Uder[o,1], Wolfgang Kemmler[a,o,*,1]

3

- **Main hypothesis: Higher net training frequencies (≥2 sessions/week)** are significantly superior in increasing BMD at the LS and the proximal femur compared with studies that applied lower training frequencies (1 to <2 sessions/week)
- **Inclusion criteria:**
  (a) controlled exercise trials
  (b) with at least two study arms that compared low versus high exercise frequency
  (c) an intervention ≥6 months
  (d) BMD assessments at lumbar spine (LS) or hip
- **Outcome measures:** Standardized mean differences for LS- and hip-BMD changes
- **7 studies** with 17 exercise groups

Review Article

The effect of different training frequency on bone mineral density in older adults. A comparative systematic review and meta-analysis

Bone 154 (2022) 116230

Anna-Lena Zitzmann[a,1], Mahdieh Shojaa[a,b,1], Stephanie Kast[a,1], Matthias Kohl[c,1], Simon von Stengel[a,1], Diana Borucki[d,1], Markus Gosch[e,1], Franz Jakob[f,1], Katharina Kerschan-Schindl[g,1], Bernd Kladny[h,1], Uwe Lange[i,1], Stefan Middeldorf[j,1], Stefan Peters[k,1], Daniel Schoene[a,1], Cornel Sieber[l,1], Friederike Thomasius[m,n,1], Michael Uder[o,1], Wolfgang Kemmler[a,o,*,1]

3

- **Significantly higher effects of high** (≥2 sessions/week) vs. low net training frequency (<2 sessions/week) exercise on LS (SMD 0.55, 95%-CI: 0.20-0.90) but not hip-BMD (0.19, -0.06 to 0.45)

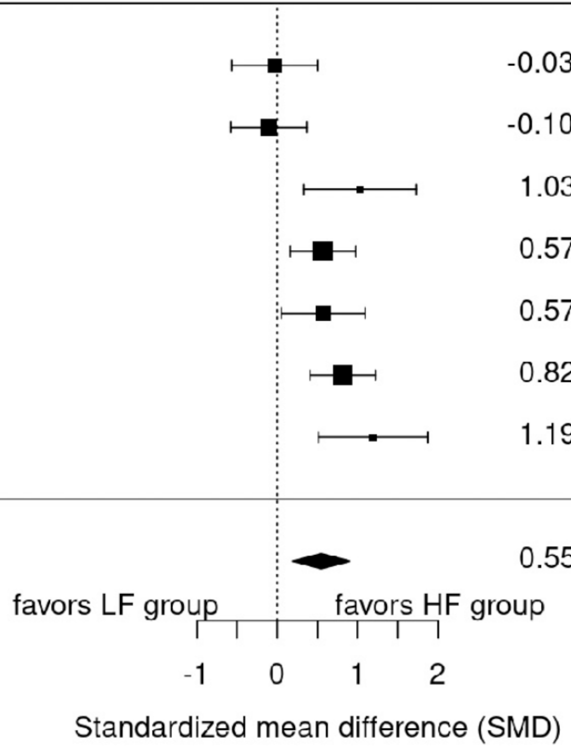
- **Study duration** is a significant moderator for the effect of training frequency at LS but not hip-BMD

- **The type of exercise moderately influences** the effect of training frequency on LS- but not on hip-BMD

Lumbar spine BMD

3

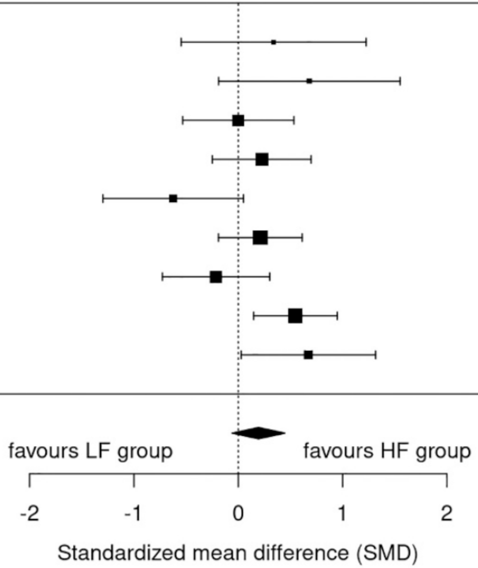
	HF		LF		
	Mean	SD	Mean	SD	
Bemben (2011HI)	0.011	0.027	0.012	0.031	-0.03 [-0.57, 0.50]
Bemben (2011LI)	0.004	0.047	0.010	0.065	-0.10 [-0.58, 0.37]
Borba-Pinheiro (2016)	0.079	0.056	0.031	0.028	1.03 [0.33, 1.73]
Cussler (2005)	0.022	0.046	-0.007	0.055	0.57 [0.16, 0.98]
Daly (2021)	0.033	0.084	-0.017	0.092	0.57 [0.05, 1.10]
Kemmler (2013)	0.023	0.028	0.002	0.019	0.82 [0.41, 1.22]
Kemmler (2014)	0.009	0.040	-0.035	0.029	1.19 [0.51, 1.87]
RE Model for All Studies ($Q = 18.82$, $df = 6$, $p = 0.004$; $I^2 = 69.7\%$)					0.55 [0.20, 0.90]



3

Random-effects Analysis of Change of Bone Mineral Density of Femoral Neck

	HF		LF		
	Mean	SD	Mean	SD	
Bailey (2010HF)	0.008	0.017	0.002	0.017	0.34 [-0.55, 1.23]
Bailey (2010VHF)	0.014	0.017	0.002	0.017	0.68 [-0.19, 1.55]
Bemben (2011HI)	0.006	0.018	0.006	0.019	0.00 [-0.53, 0.53]
Bemben (2011LI)	0.008	0.023	0.003	0.021	0.22 [-0.25, 0.70]
Borba-Pinheiro (2016)	0.074	0.054	0.115	0.076	-0.62 [-1.30, 0.05]
Cussler (2005)	0.004	0.037	-0.005	0.047	0.21 [-0.19, 0.61]
Daly (2021)	0.003	0.024	0.008	0.021	-0.21 [-0.73, 0.30]
Kemmler (2013)	0.006	0.020	-0.004	0.013	0.55 [0.15, 0.95]
Kemmler (2014)	-0.037	0.031	-0.057	0.026	0.67 [0.03, 1.32]
RE Model for All Studies ($Q = 15.02$, $df = 8$, $p = 0.059$; $I^2 = 46.6\%$)					0.19 [-0.06, 0.45]



Conclusions

Review Article

The effect of different training frequency on bone mineral density in older adults. A comparative systematic review and meta-analysis

Anna-Lena Zitzmann[a,1], Mahdieh Shojaa[a,b,1], Stephanie Kast[a,1], Matthias Kohl[c,1], Simon von Stengel[a,1], Diana Borucki[d,1], Markus Gosch[e,1], Franz Jakob[f,1], Katharina Kerschan-Schindl[g,1], Bernd Kladny[h,1], Uwe Lange[i,1], Stefan Middeldorf[j,1], Stefan Peters[k,1], Daniel Schoene[a,1], Cornel Sieber[l,1], Friederike Thomasius[m,n,1], Michael Uder[o,1], Wolfgang Kemmler[a,o,*,1]

- **Both exercise with lower** (i.e. <2 sessions/week) and **higher** (≥2 sessions per week) training frequency **favourably affect BMD at the LS and hip**
- **Higher training frequency** was associated with much higher treatment effects on BMD
- The considerable difference in LS-BMD changes is **worth "to train a little more often"**
- **Exercise programs for osteoporosis** that consistently applied **3 sessions/week/year** have to be provided, so that participants can achieve a **net training frequency** of at least two sessions per week

Pinheiro *et al. International Journal of Behavioral Nutrition and Physical Activity* (2020) 17:150
https://doi.org/10.1186/s12966-020-01040-4

International Journal of Behavioral Nutrition and Physical Activity

4

REVIEW **Open Access**

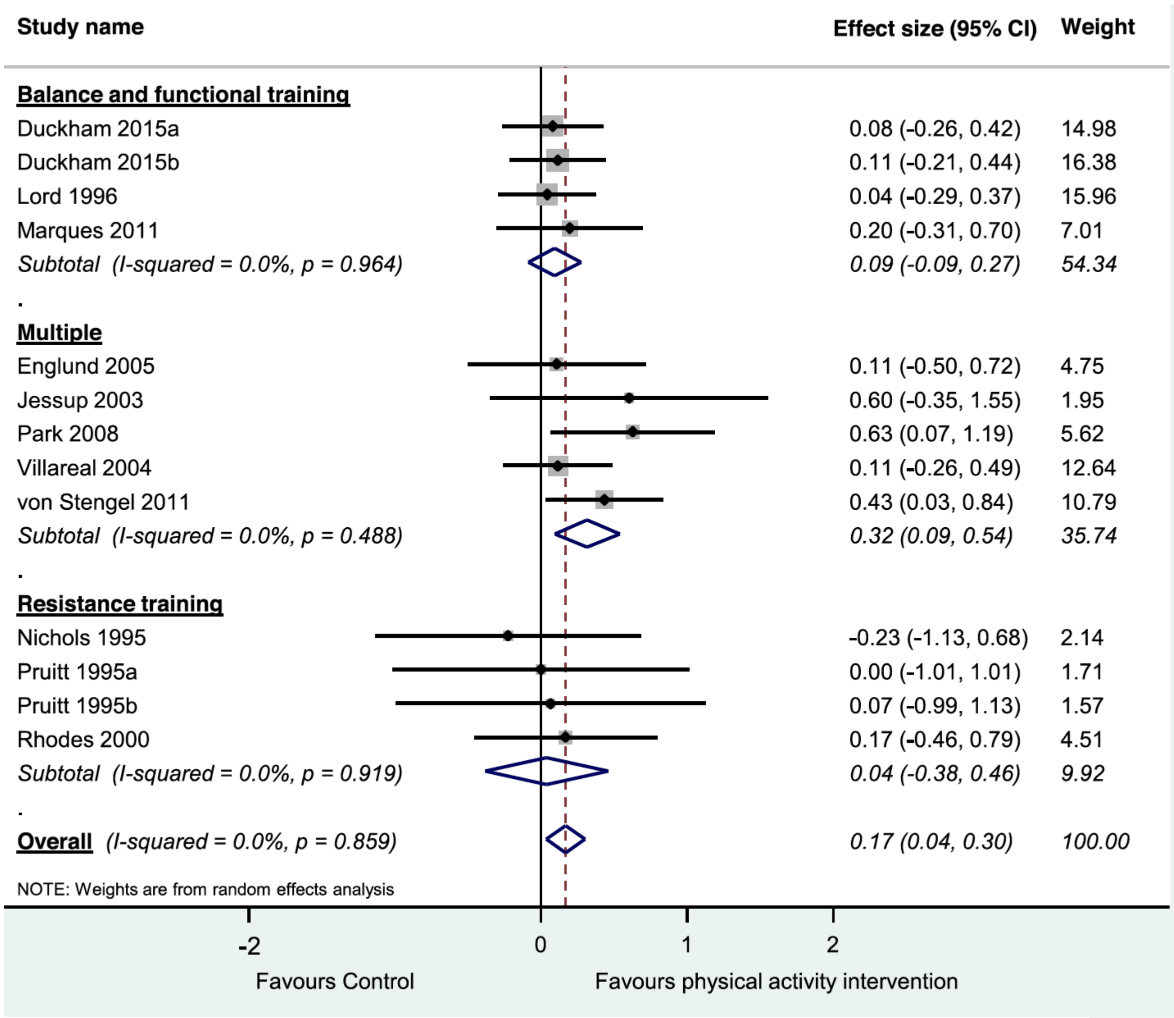
Check for updates

Evidence on physical activity and osteoporosis prevention for people aged 65+ years: a systematic review to inform the WHO guidelines on physical activity and sedentary behaviour

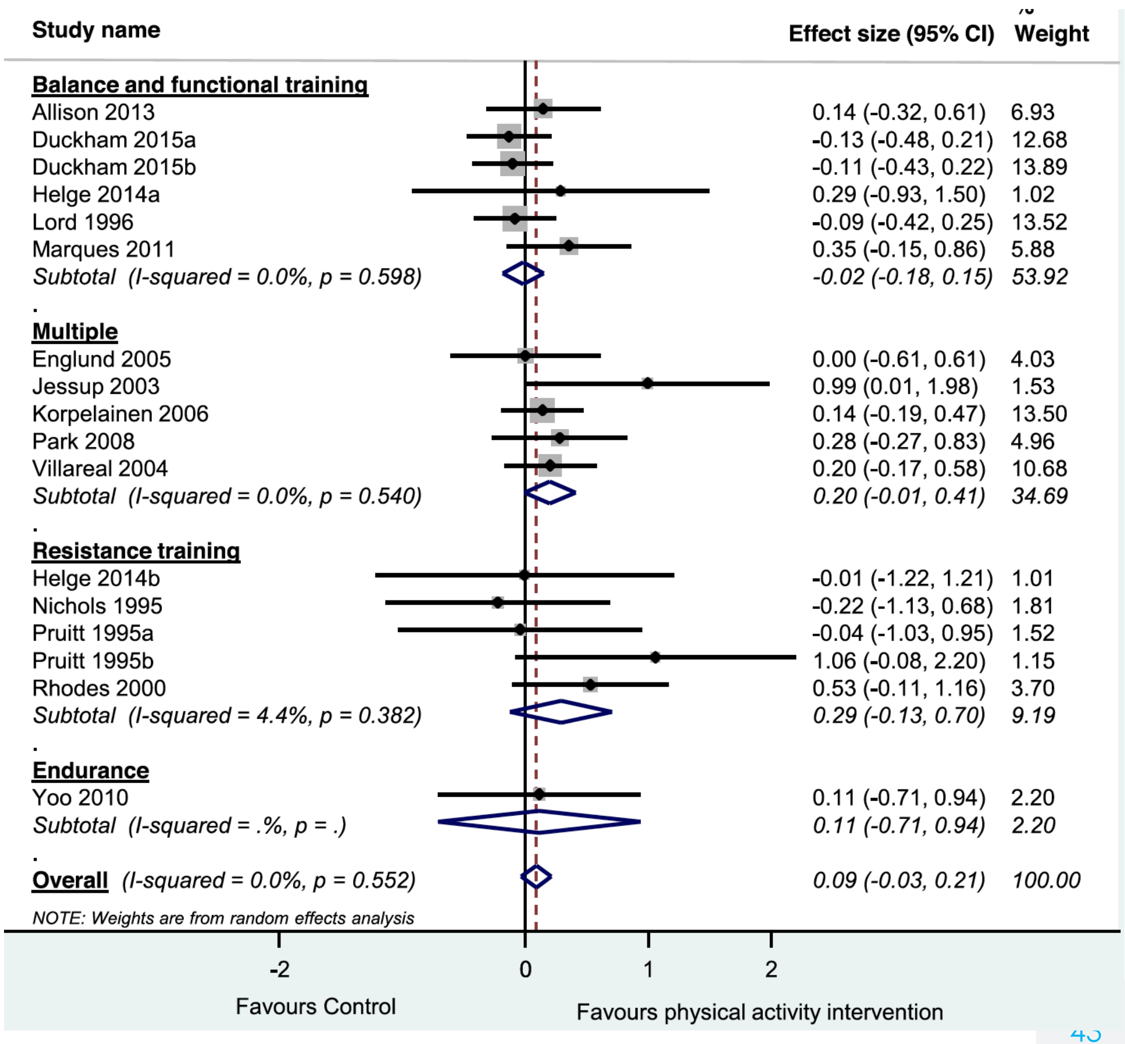
Marina B. Pinheiro[1,2*], Juliana Oliveira[1,2], Adrian Bauman[3], Nicola Fairhall[1,2], Wing Kwok[1,2] and Catherine Sherrington[1,2]

- **Physical activity** probably plays a role in the prevention of osteoporosis
- The **level of evidence is higher** for effects of physical activity on lumbar spine bone mineral density than for hip
- **Higher dose programs** and those involving multiple exercises and resistance exercises appear to be more effective

- Effect size (95% CI) of **physical activity interventions on the lumbar spine BMD**
- Pooling data from 11 studies comparing physical activity versus control using random-effects meta-analysis (n = 874)



- Effect size (95% CI) of **physical activity interventions on the femoral BMD**
- Pooling data from 14 studies comparing physical activity versus control using random-effects meta-analysis (n = 1032)

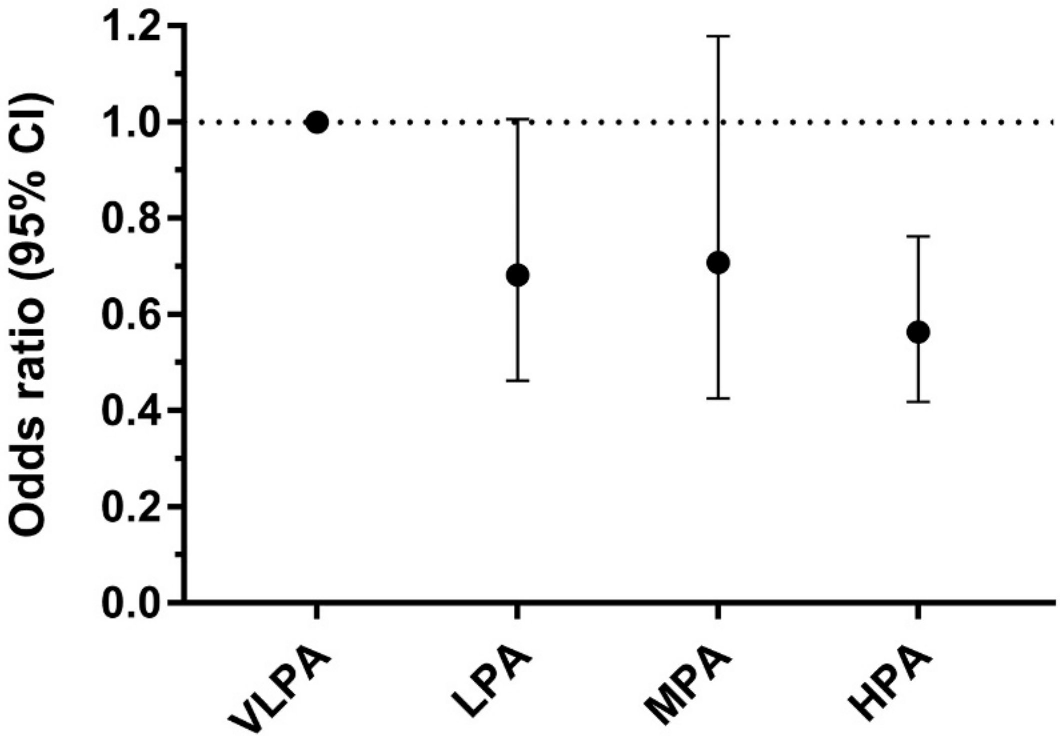


Odds ratio for Osteoporosis

adjusted by age, sex, race/ethnicity, annual household income, educational level, smoking status, alcohol consumption and obesity.

4

- Only the most active group **(>1800 MET-min/week)** is protected against osteoporosis.



Review Article

Bone, 2021

The effect of exercise intensity on bone in postmenopausal women (part 1): A systematic review

Melanie Kistler-Fischbacher [a,b], Benjamin K. Weeks [a,b], Belinda R. Beck [a,b,c,*]

[a] Menzies Health Institute Queensland, Griffith University, Gold Coast campus, Gold Coast, QLD, Australia
[b] School of Allied Health Sciences, Griffith University, Gold Coast campus, Gold Coast, QLD, Australia
[c] The Bone Clinic, Brisbane, QLD, Australia

5

- **100 trials** were included, investigating a total of 120 exercise interventions
- **57** interventions were low intensity
- **57** were moderate
- **6** were high intensity

Exercise Intensity Classification

Bone, 2021

	Low intensity	Moderate intensity	High intensity
Resistance training	>15 reps <65% 1 RM	8–15 reps 65–80% 1 RM	<6 reps >80% 1 RM
GRF	<2 × bodyweight	2–4 × bodyweight	>4 × bodyweight
Examples activities	Walking, jogging, cycling, aquatic interventions, tai chi, bodyweight exercises, resistance training using elastic bands or anything described as 'small' or 'light' weights	Heel drops, rope skipping, aerobics, jumps with soft landing (e.g. on a soft pad) or with knees and hips bent	Jumps with stiff-legged landing

5

Review Article

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[a] *Menzies Health Institute Queensland, Griffith University, Gold Coast campus, Gold Coast, QLD, Australia*
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[c] *The Bone Clinic, Brisbane, QLD, Australia*

Bone, 2021

5

- **Low intensity exercise** was not an effective stimulus to increase bone mass
- **Moderate to high intensity** interventions, particularly those that combined high intensity resistance and impact training, were most beneficial for bone mass
- **Only high intensity exercise** appears to improve structural parameters of bone strength, however, data are limited
- **Only low and moderate intensity** interventions have measured BTMs and no notable benefits have been observed

Review Article

The effect of exercise intensity on bone in postmenopausal women (part 1): A systematic review

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Bone, 2021

5

- The **quality of trials** varied greatly
- **Risk of bias** determinations were frequently limited by insufficiently reported detail
- **Heterogeneity in both study quality and outcomes** limits the ability to draw strong conclusions from this comprehensive systematic review of RCT and CT reports
- **Tendency in the higher quality data** to indicate exercise intensity is positively related to the adaptive bone response

Review Article

The effect of exercise intensity on bone in postmenopausal women (part 2): A meta-analysis

Melanie Kistler-Fischbacher [a,b], Benjamin K. Weeks [a,b], Belinda R. Beck [a,b,c,*]

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6

- To **determine the effects** of low, moderate and high intensity exercise on BMD at the spine and hip in postmenopausal women
- **53 trials**
- Testing **63 interventions** (19 low, 40 moderate, 4 high intensity)

Review Article

The effect of exercise intensity on bone in postmenopausal women (part 2): A meta-analysis

Melanie Kistler-Fischbacher[a,b], Benjamin K. Weeks[a,b], Belinda R. Beck[a,b,c,*]

[a] *Menzies Health Institute Queensland, Griffith University, Gold Coast campus, Gold Coast, QLD, Australia*
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[c] *The Bone Clinic, Brisbane, QLD, Australia*

6

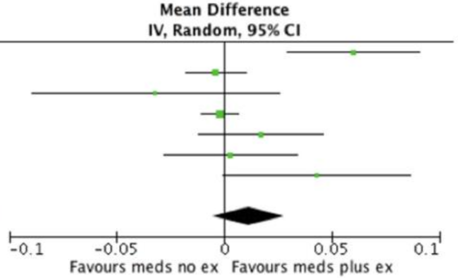
- **At the lumbar spine:**
- **High intensity exercise** yielded greater BMD effects (MD=0.031 g/cm², 2 95% CI 0.012, 0.049, p = 0.002) than moderate (MD = 0.012 g/cm² , 95% CI 0.008, 0.017, p < 0.001) and low intensity (MD = 0.010 g/cm² , 95% CI 0.005, 0.015, p < 0.001)
- **Low and moderate intensity exercise** was equally effective at the femoral neck (low: 0.011 g/cm² 95% CI 0.006, 0.016, p < 0.001; moderate: 0.011 g/cm² 95% CI 0.007, 0.015, p < 0.001), but no effect of high-intensity exercise was observed
- **Moderate intensity exercise** increased total hip BMD (0.008 g/cm² 95% CI 0.004, 0.012, p < 0.001), but low intensity did not
- There were **insufficient data to meta-analyse the effect of high intensity exercise at the total hip**

- Forest plot of meta-analyses results of the **combined effect of exercise and medication on BMD** a the lumbar spine (a), femoral neck (b) and total hip (c).
- Mean, SD, MD and 95% CI are g/cm^2

a. Lumbar spine

Study or Subgroup	Meds plus ex Mean	SD	Total	Meds no ex Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Angin 2015	0.04	0.06	22	-0.02	0.04	19	13.3%	0.0600 [0.0291, 0.0909]
Bassey 1998	0.014	0.029	24	0.018	0.019	22	20.9%	-0.0040 [-0.0181, 0.0101]
Chilibeck 2002	0.002	0.073	12	0.034	0.077	14	6.2%	-0.0320 [-0.0897, 0.0257]
Going 2003	0.009	0.022	71	0.011	0.028	65	23.1%	-0.0020 [-0.0105, 0.0065]
Maddalozzo 2007	0.01	0.059	33	-0.007	0.062	34	14.1%	0.0170 [-0.0120, 0.0460]
Uusi-Rasi 2003	0.034	0.066	38	0.031	0.072	38	13.2%	0.0030 [-0.0281, 0.0341]
Watson 2018	0.041	0.061	9	-0.002	0.0274	10	9.2%	0.0430 [-0.0003, 0.0863]
Total (95% CI)			**209**			**202**	**100.0%**	**0.0114 [-0.0051, 0.0280]**

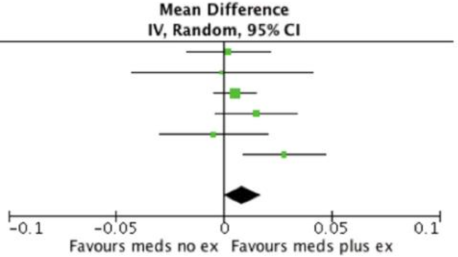
Heterogeneity: Tau² = 0.00; Chi² = 20.92, df = 6 (P = 0.002); I² = 71%
Test for overall effect: Z = 1.35 (P = 0.18)



b. Femoral neck

Study or Subgroup	Meds plus ex Mean	SD	Total	Meds no ex Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Bassey 1998	0.001	0.034	24	-0.001	0.033	22	15.9%	0.0020 [-0.0174, 0.0214]
Chilibeck 2002	-0.001	0.048	12	0	0.061	14	4.2%	-0.0010 [-0.0429, 0.0409]
Going 2003	0.012	0.029	71	0.007	0.029	65	36.3%	0.0050 [-0.0048, 0.0148]
Maddalozzo 2007	-0.005	0.041	33	-0.02	0.038	34	16.4%	0.0150 [-0.0039, 0.0339]
Uusi-Rasi 2003	0.009	0.052	38	0.014	0.059	38	10.6%	-0.0050 [-0.0300, 0.0200]
Watson 2018	0.015	0.019	9	-0.013	0.023	10	16.5%	0.0280 [0.0091, 0.0469]
Total (95% CI)			**187**			**183**	**100.0%**	**0.0087 [-0.0002, 0.0176]**

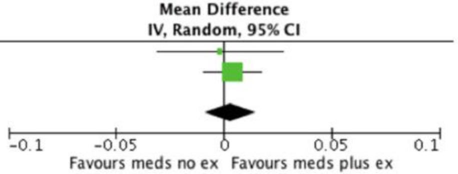
Heterogeneity: Tau² = 0.00; Chi² = 6.77, df = 5 (P = 0.24); I² = 26%
Test for overall effect: Z = 1.91 (P = 0.06)



c. Total hip

Study or Subgroup	Meds plus ex Mean	SD	Total	Meds no ex Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Chilibeck 2002	-0.002	0.025	12	0	0.049	14	17.3%	-0.0020 [-0.0313, 0.0273]
Maddalozzo 2007	0.001	0.028	33	-0.003	0.028	34	82.7%	0.0040 [-0.0094, 0.0174]
Total (95% CI)			**45**			**48**	**100.0%**	**0.0030 [-0.0092, 0.0152]**

Heterogeneity: Tau² = 0.00; Chi² = 0.13, df = 1 (P = 0.72); I² = 0%
Test for overall effect: Z = 0.48 (P = 0.63)



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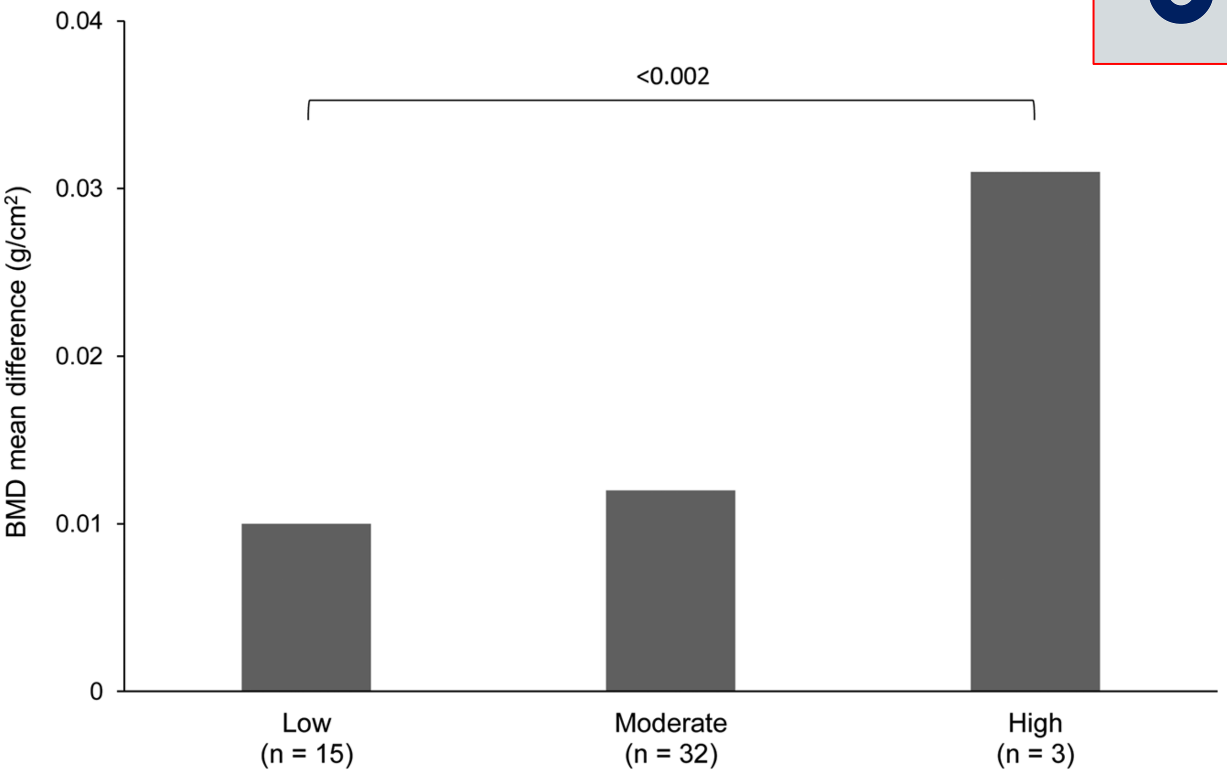
- **High-intensity exercise** improves **lumbar spine BMD** more effectively than low- or moderate-intensity exercise



Review Article

The effect of exercise intensity on bone in postmenopausal women (part 2): A meta-analysis

Melanie Kistler-Fischbacher [a,b], Benjamin K. Weeks [a,b], Belinda R. Beck [a,b,c,*]

[a] Menzies Health Institute Queensland, Griffith University, Gold Coast campus, Gold Coast, QLD, Australia
[b] School of Allied Health Sciences, Griffith University, Gold Coast campus, Gold Coast, QLD, Australia
[c] The Bone Clinic, Brisbane, QLD, Australia

7

- **Conclusion:**
- **Resistance training**, potentially in combination with impact training, appears to be the most effective osteogenic stimulus at the spine and hip
- **High intensity exercise** is a more effective stimulus for **lumbar spine BMD** than low or moderate intensity, but **not femoral neck BMD**, however, the latter finding may be due to lack of power
- While data from high-intensity exercise interventions are limited, there is a **positive relationship** between load magnitude and bone response in humans as observed in animal research

Osteoporosis International (2020) 31:1427–1444
https://doi.org/10.1007/s00198-020-05441-w

REVIEW

8

Effects of dynamic resistance exercise on bone mineral density in postmenopausal women: a systematic review and meta-analysis with special emphasis on exercise parameters

M. Shojaa[1] · S. von Stengel[1] · M. Kohl[2] · D. Schoene[1] · W. Kemmler[1]

- Determine the effect of **dynamic resistance exercise (DRT)** on areal BMD in postmenopausal women

- **Included:** (a) controlled trials, (b) of isolated DRT with at least one exercise and one control group, (c) with intervention durations ≥ 6 months, (d) aBMD assessments at lumbar spine or proximal femur, (e) in cohorts of postmenopausal women

- **17 articles** with 20 exercise and 18 control groups were eligible

Osteoporosis International (2020) 31:1427–1444
https://doi.org/10.1007/s00198-020-05441-w

REVIEW

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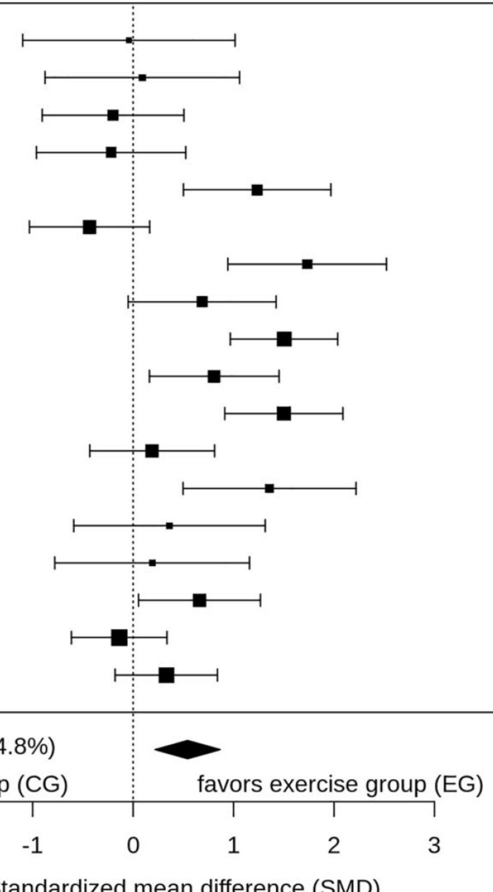
M. Shojaa[1] · S. von Stengel[1] · M. Kohl[2] · D. Schoene[1] · W. Kemmler[1]

- **SMD** average is 0.54 (95% CI 0.22–0.87) for LS-BMD, 0.22 (0.07–0.38) for FN-BMD, and 0.48 (0.22–0.75) for TH-BMD changes (all $p \leq 0.015$)
- While sub-group analysis for FN-BMD revealed no differences within categories of moderators, **lower training frequency** (< 2 sessions/week) resulted in **significantly higher BMD changes** at LS and TH compared to higher training frequency (≥ 2 sessions/week)
- **Free weight training** was significantly superior to DRT devices for improving TH-BMD

8

Random-effects Analysis of LS data

Study	EG Mean	EG SD	CG Mean	CG SD	SMD [95% CI]
Bemben (2000HI)	-0.009	0.024	-0.008	0.018	-0.04 [-1.10, 1.02]
Bemben (2000LI)	-0.006	0.022	-0.008	0.018	0.09 [-0.88, 1.06]
Bemben (2010)	-0.007	0.023	-0.002	0.027	-0.20 [-0.90, 0.51]
Chilibeck (2002)	-0.007	0.025	-0.002	0.019	-0.22 [-0.96, 0.52]
De Oliveira (2018)	0.020	0.020	0.000	0.010	1.23 [0.50, 1.97]
Duff (2016)	-0.003	0.028	0.011	0.035	-0.43 [-1.03, 0.16]
Hartard (1996)	0.003	0.036	-0.054	0.027	1.73 [0.94, 2.52]
Kohrt (1997RE)	0.013	0.014	0.002	0.017	0.69 [-0.05, 1.42]
Maddalozzo (2006)	0.002	0.023	-0.042	0.034	1.50 [0.97, 2.04]
Nelson (1994)	0.009	0.033	-0.019	0.035	0.81 [0.16, 1.45]
Nicholson (2015)	0.011	0.021	-0.023	0.024	1.50 [0.91, 2.09]
Orsatti (2013)	-0.005	0.027	-0.010	0.025	0.19 [-0.43, 0.81]
Pruitt (1992)	0.012	0.024	-0.023	0.027	1.36 [0.50, 2.22]
Pruitt (1995HI)	0.007	0.018	0.000	0.020	0.36 [-0.59, 1.32]
Pruitt (1995LI)	0.005	0.027	0.000	0.020	0.19 [-0.78, 1.16]
Rhodes (2000)	0.020	0.032	0.000	0.027	0.66 [0.05, 1.27]
Sinaki (1989)	-0.015	0.031	-0.011	0.026	-0.14 [-0.61, 0.34]
Woo (2007RE)	0.013	0.021	0.007	0.014	0.33 [-0.18, 0.84]
RE Model for All Studies ($Q = 70.09$, $df = 17$, $p < 0.001$; $I^2 = 74.8\%$)					0.54 [0.22, 0.87]



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REVIEW

8

Effects of dynamic resistance exercise on bone mineral density in postmenopausal women: a systematic review and meta-analysis with special emphasis on exercise parameters

M. Shojaa[1] · S. von Stengel[1] · M. Kohl[2] · D. Schoene[1] · W. Kemmler[1]

- Evidence for significant, albeit only low–moderate, effects of DRT on LS, FN, TH-BMD
- Sub-analysis results **did not allow meaningful exercise recommendations** to be derived
- Significant **low–moderate effect of dynamic resistance exercise on BMD** changes in postmenopausal women

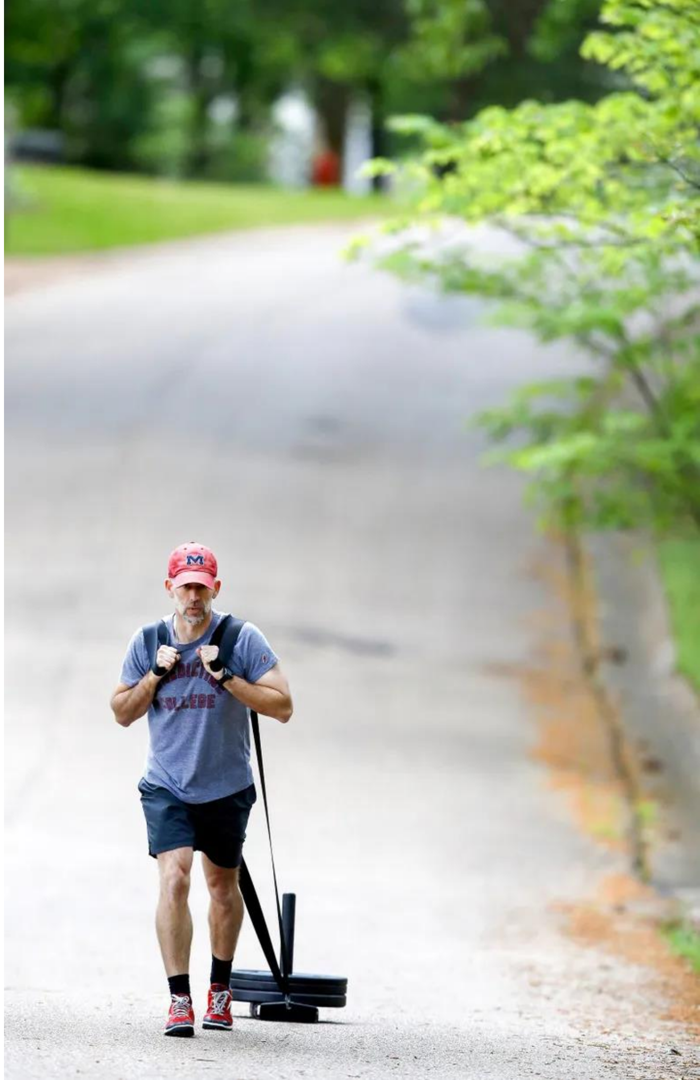
*Take home message

- **Encourage** people with osteoporosis to do more exercise
- **Recommend** challenging balance exercises
- **Advise** patients that there is little evidence of harm associated with exercise
- **Promote** caring for the spine and strengthening back muscles
- **Know** which exercises promote bone strength
  - To promote bone strength a combination of weight-bearing exercise involving impact, and muscle strengthening exercise is recommended
  - Both types of exercise may provide some benefit alone, but they are most effective when combined

*Take home message

- To promote bone strength a **combination of weight-bearing exercise** involving impact, and muscle strengthening exercise is recommended

- Both types of exercise may provide some benefit alone, but they are **most effective when combined**



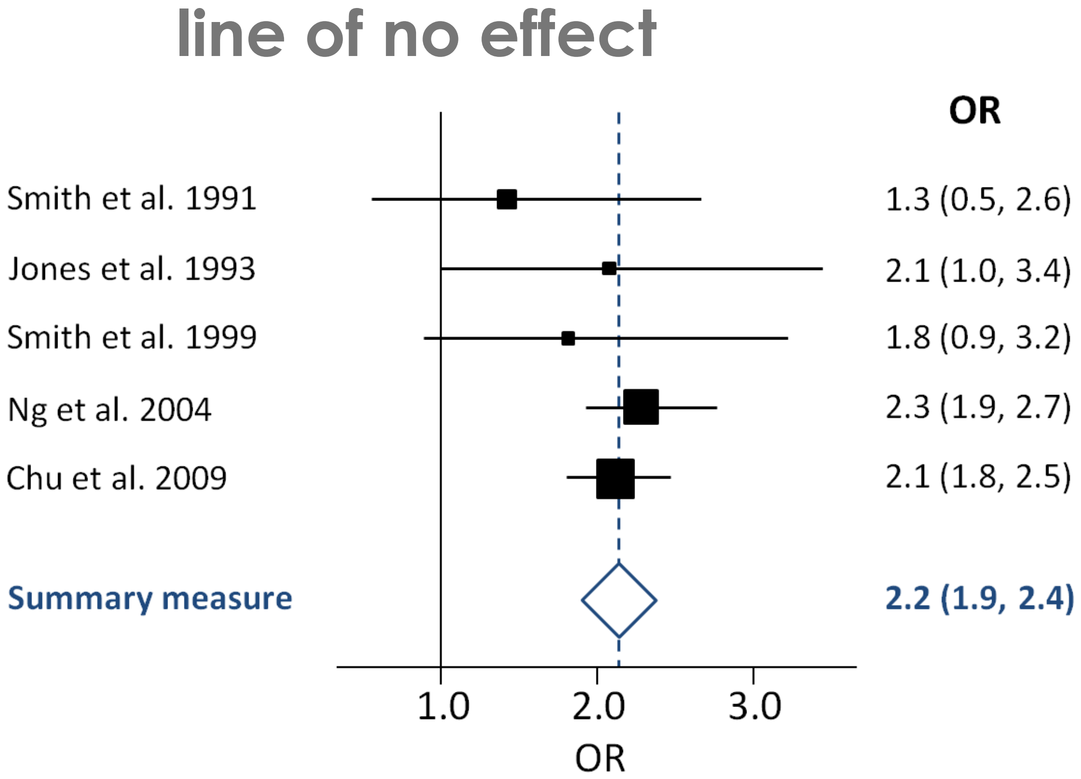
Odds ratio

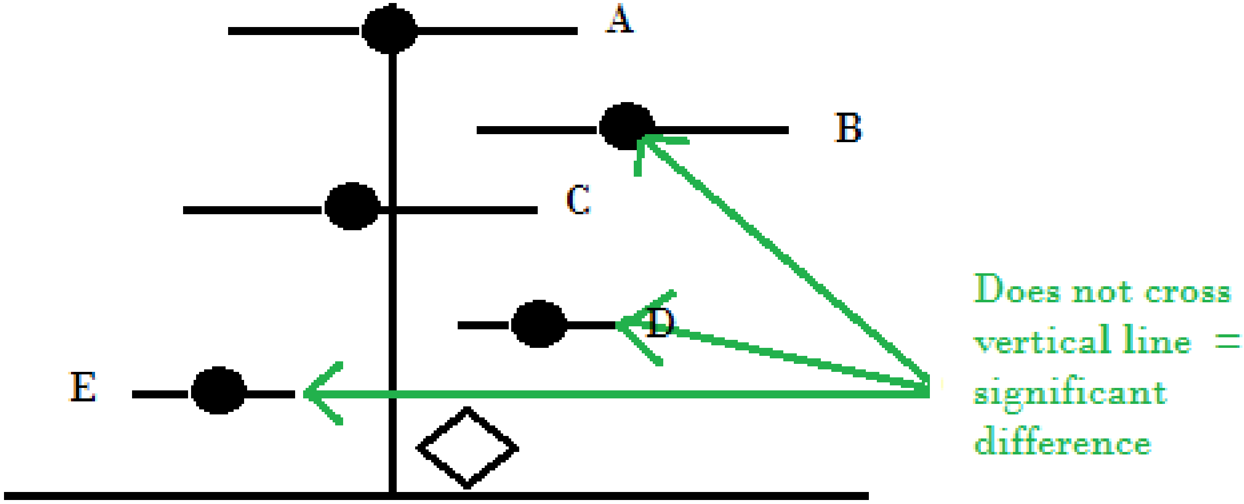
- λόγος σχετικών πιθανοτήτων
- comparison of chances that [sth] will occur to chances it will not

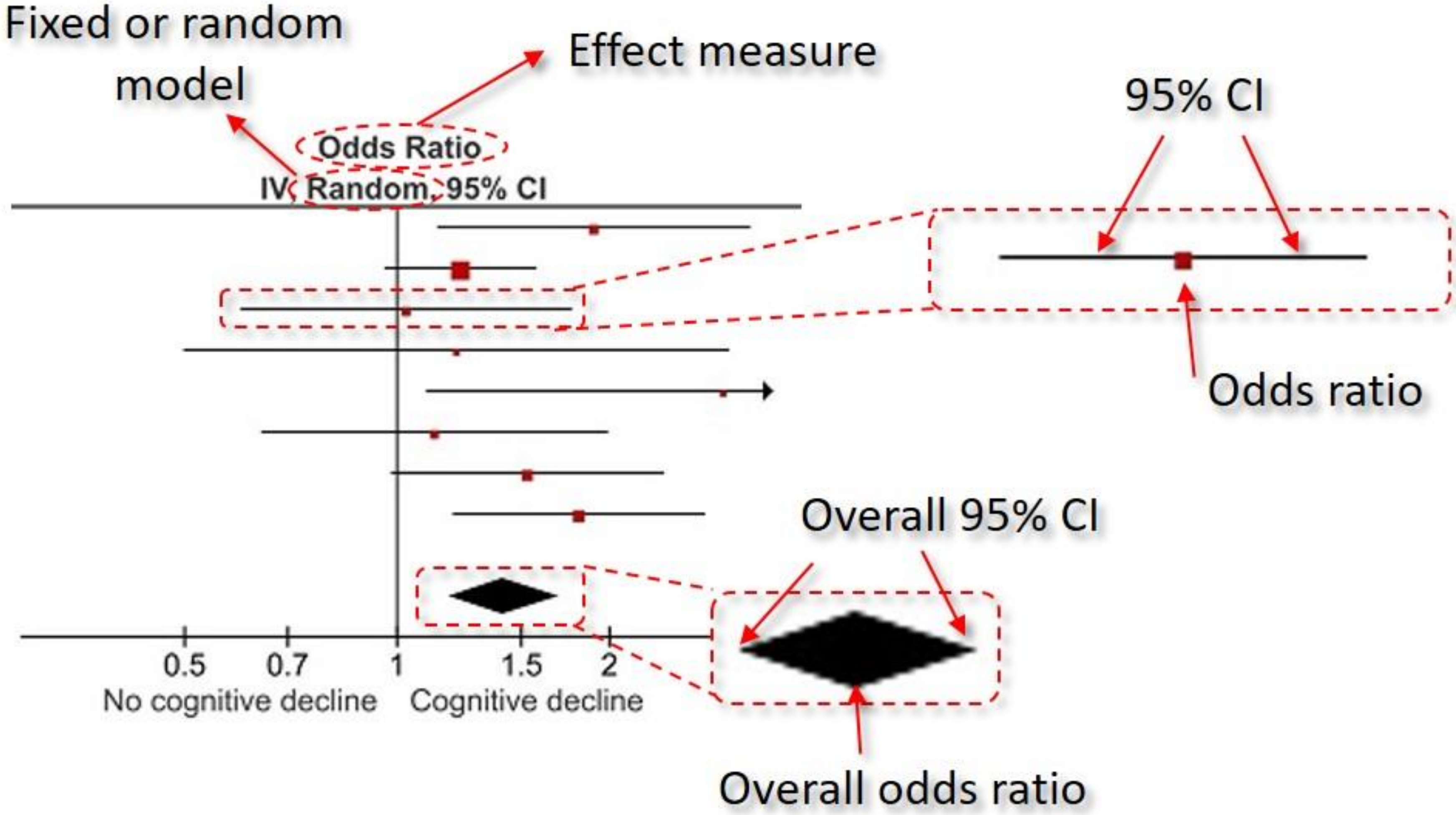
- OR=1 καμία επίδραση παράγοντα
- OR>1 βλαπτική επίδραση
- OR<1 προστατευτική επίδραση

Forest plot, blobbogram

- graphical display of estimated results from a number of scientific studies addressing the same question

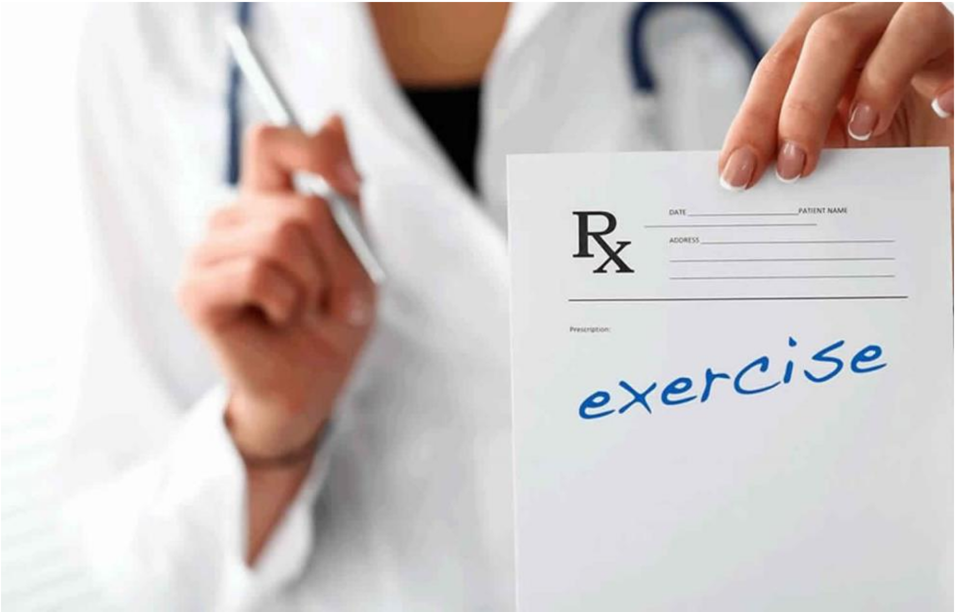



A
B
C
D
E
Does not cross vertical line = significant difference



Fixed or random model
Effect measure
Odds Ratio
IV, Random, 95% CI
95% CI
Odds ratio
Overall 95% CI
0.5
0.7
1
1.5
2
No cognitive decline
Cognitive decline
Overall odds ratio

- Osteoporosis Exercise Prescription



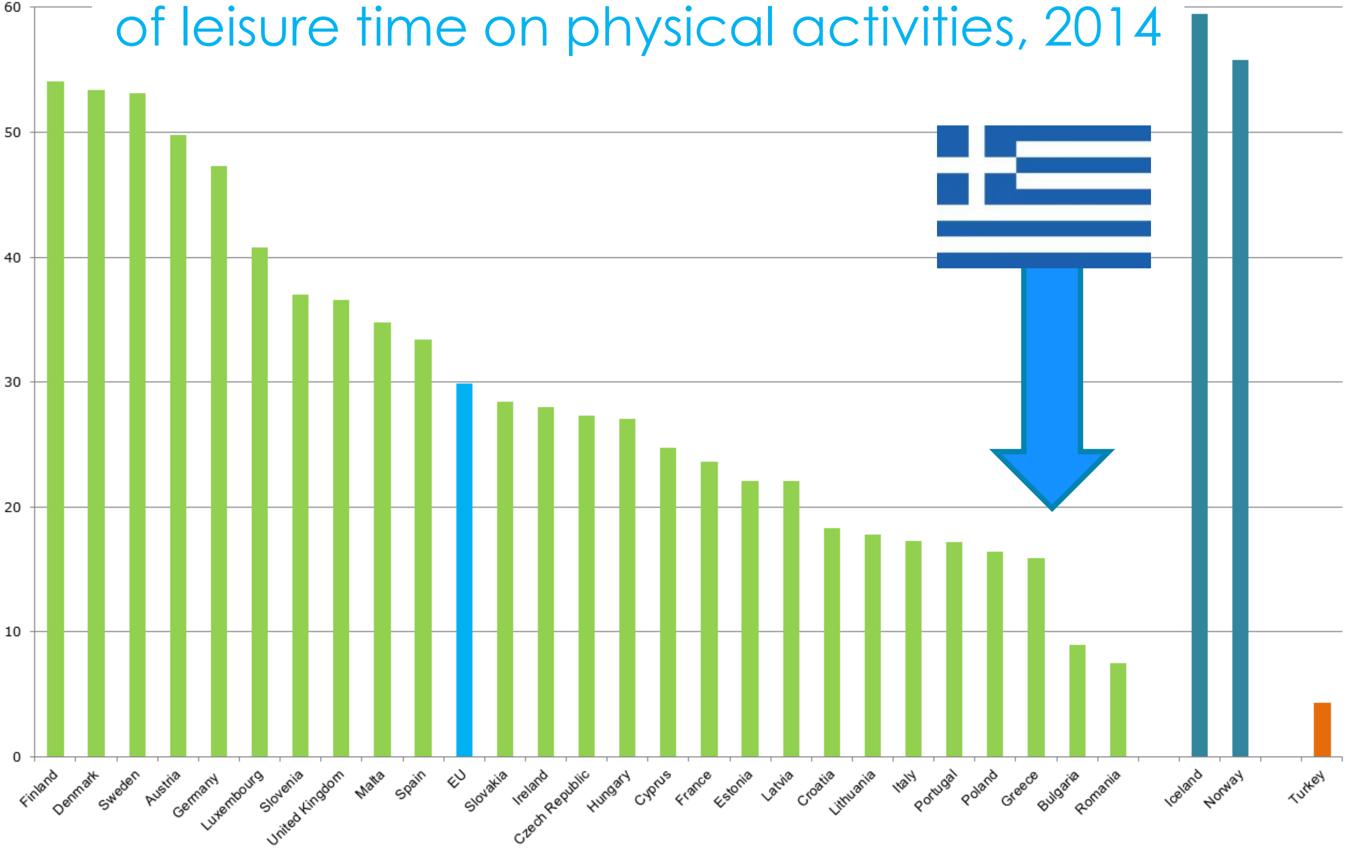
Exercise Goals for Osteoporosis

- Muscle strength and endurance
- Balance and stability
- Mobility and quality of life
- Prevention of falls

Accredited Exercise Program for Osteoporosis
Evidence–based, developed from the LIFTMOR study

- https://onero.academy/osteoporosis-exercises

% **People** spending at least 2,5 hrs/week of leisure time on physical activities, 2014



Belgium and the Netherlands: data not available

COMPONENTS OF FITNESS FOR HEALTH

CARDIORESPIRATORY ENDURANCE

Our ability to perform an activity, with our heart rate elevated, for a certain amount of time.

MUSCULAR STRENGTH

Our ability to exert force during an activity.

FLEXIBILITY/MOBILITY

The range of motion around our joints.

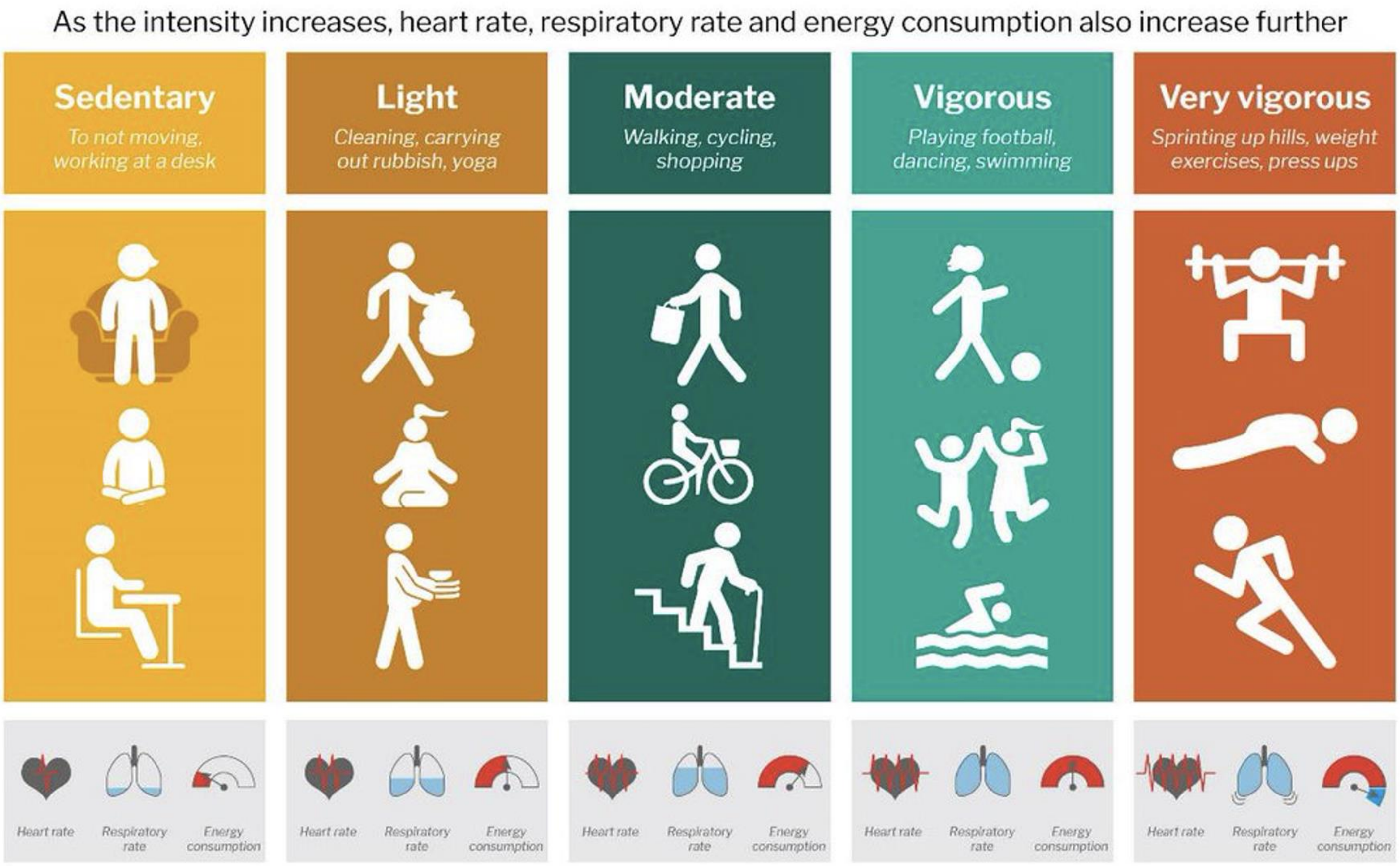
MUSCULAR ENDURANCE

The ability of our muscles to continue to perform an activity without fatiguing.

BODY COMPOSITION

The amount of body fat, muscle, bone and other tissues that make up our body.

Intensity of Exercise

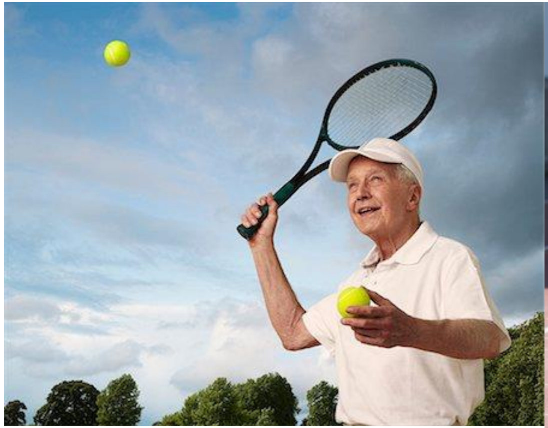


Intensity of Exercise - Metabolic Equivalent

Activity Level	MET	Activity
Very Light	1.3-2	standing, reading, sitting, studying
Light	2-3	walking at a slow pace (1-2 mi/hr), playing musical instrument, light gardening, light office work, shopping
Moderately Vigorous	3-5	walking at a brisk pace (1 mi every 20 min), weight lifting, water aerobics, climbing stairs, gardening, golf
Vigorous	6-16	ice or roller skating, rowing, canoeing, squash, running

Weight-bearing Exercise Involving Impact

- Advised to exercise **up to a 'moderate' impact level**
- Provided a patient does not have a vertebral fracture or multiple fragility fractures
- This includes:
  - racquet sports
  - running or jogging
  - jumping/hopping
  - dancing
  - track events



Patients with Vertebral Fractures or Multiple Fragility Fractures

- Start exercising at **low impact levels** (e.g. Nordic walking, stair climbing, marching, walking, side steps)

- **Increasing to moderate levels** depending on factors such as number of fractures and whether back pain has resolved

- **No recommendations are made about higher-impact exercise** (e.g. exertional jumps such as high vertical jumps, star jumps) as there is no evidence that this type of exercise is beneficial or safe for people with osteoporosis

- All patients should **build up their levels of physical activity and exercise slowly**, taking into account their ability and experience

Posture Exercise

- Good posture is important
- Can minimize kyphosis and reduce the risk of spine fractures
- Try to work on good posture several times a day

Balance Exercise

- Can reduce chance of falls&fractures
- Should be challenging, but safety is the first priority

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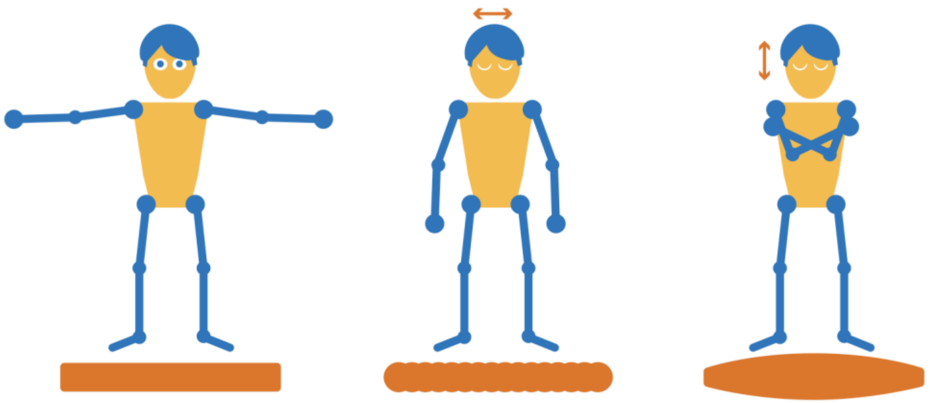
BALANCE EXERCISE



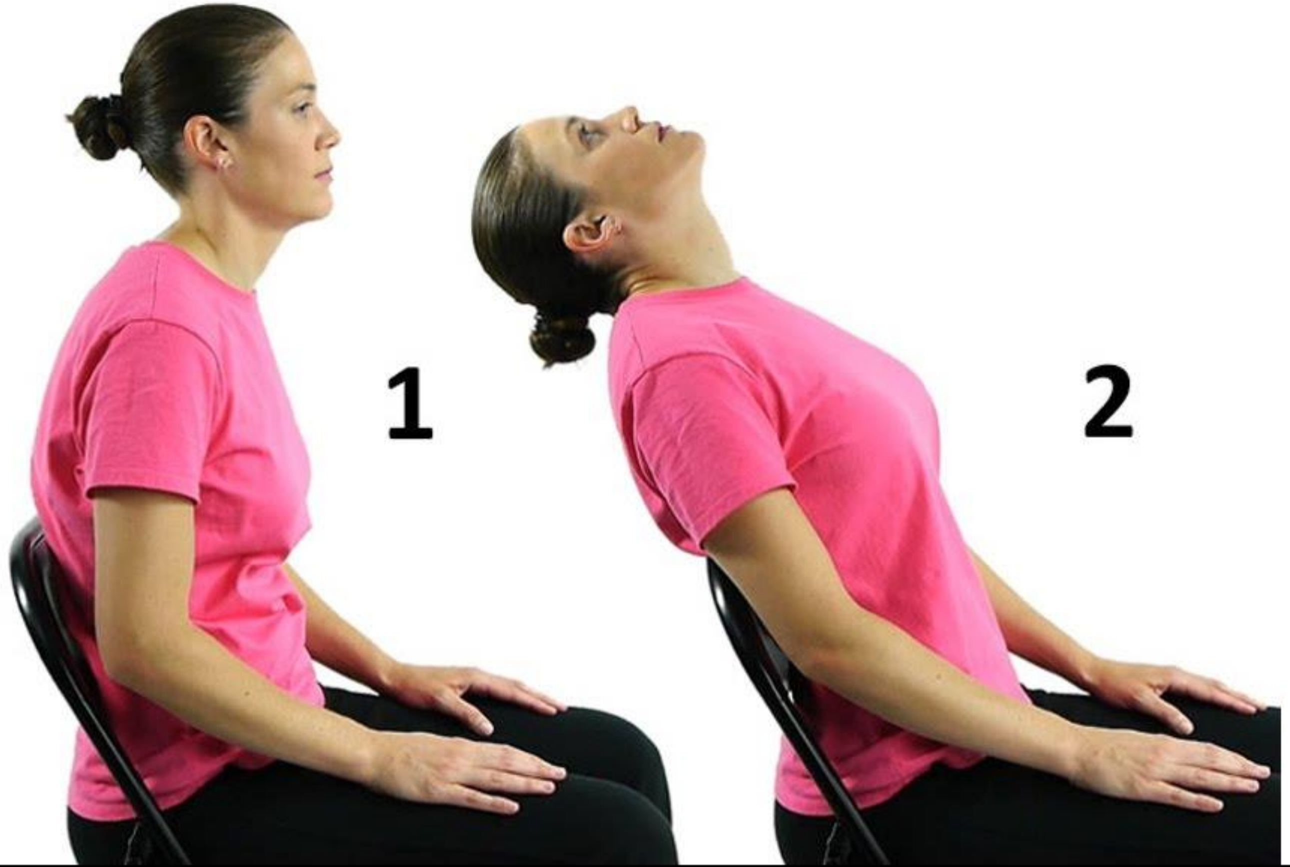
* Use extreme caution

Yoga and Pilates? Helpful or not?

- Helpful for stretching and lengthening
- Include many flexion- and extension-based poses

Exercises to Avoid in Osteoporosis

- Dynamic abdominal exercises (e.g. sit-ups)
- Twisting movements (e.g. golf swing)
- Trunk flexion
- Abrupt or explosive loading
- High impact loading



Seated Thoracic Extension