

Biofeedback load technique in the rehabilitation of osteoporotic patients (Biomechanical analysis)

J. Wendlová

Osteology Unit, Derer's University Hospital and Policlinic Bratislava, Slovakia, head Ass. Prof. Jaroslava Wendlová, MD, PhD.

Summary: Based on a simple biomechanical analysis, available to physicians, the article recommends carrying a backpack regularly as a part of the complex rehabilitation of osteoporotic patients. Carrying a backpack in front or on the back is recommended for patients with uncomplicated osteoporosis, carrying a backpack only on the back is recommended for patients with osteoporotic vertebrae fractures. The importance of carrying a backpack is based upon remove the muscular dysbalance of the trunk muscles and upon increasing the bone strength by compressive force acting upon the vertebrae and proximal femur and activating osteoblasts to osteoformation. The backpack load magnitude is differentiated – patients with vertebrae fractures put a weight up to 1 kg into the backpack, patients without vertebrae fractures up to 2 kg.

Key words: osteoporosis – vertebral fracture – biomechanics – rehabilitation – backpack – muscular dysbalance

Technika zaťažovania skeletu so spätnou väzbou v rehabilitácii osteoporotického pacienta (Biomechanická analýza)

Súhrn: V článku na základe jednoduchkej biomechanickej analýzy, dostupnej lekárskej verejnosti, odporúčame pravidelné nosenie rucksaku ako súčasť komplexnej rehabilitácie osteoporotického pacienta. Nosenie rucksaku vpredu a vzadu odporúčame pre pacientov s nekomplikovanou osteoporózou a nosenie rucksaku len vzadu pre pacientov s osteoporotickými zlomeninami stavcov. Význam nosenia rucksaku spočíva vo vyrovnaní svalovej dysbalancie svalstva trupu a v zvyšovaní pevnosti kosti vplyvom tlakovej sily pôsobiacej na stavce a proximálne femury, ktorá aktivuje osteoblasty k osteoformácii. Diferencujeme veľkosť zaťaženia v rucksaku – pacienti so zlomeninami stavcov si do rucksaku umiestnia záťaž o hmotnosti do 1 kg, pacienti bez zlomenín stavcov o hmotnosti do 2 kg.

Kľúčové slová: osteoporóza – biomechanika – rehabilitácia – nosenie rucksaku – svalová dysbalancia – aktivácia osteoformácie

Introduction

The aim of this short statement is to explain the benefits of carrying a backpack in the rehabilitation of osteoporotic patients on the basis of a simple biomechanical analysis available to physicians.

Carrying a backpack alternately **in front and on the back** is recommended for patients:

- with vertebral osteopenia and osteoporosis (without vertebrae fractures) and muscular dysbalance of the trunk muscles (fig. 1),
effect: remove the muscular dysbalance of the trunk musculature, activating osteoblasts to neoformation of bone by compressive forces acting upon vertebrae [1–5], increasing the bone strength;
- with osteopenia and osteoporosis in the area of proximal femur,
effect: stimulation of osteoblasts to osteoformation by compressive

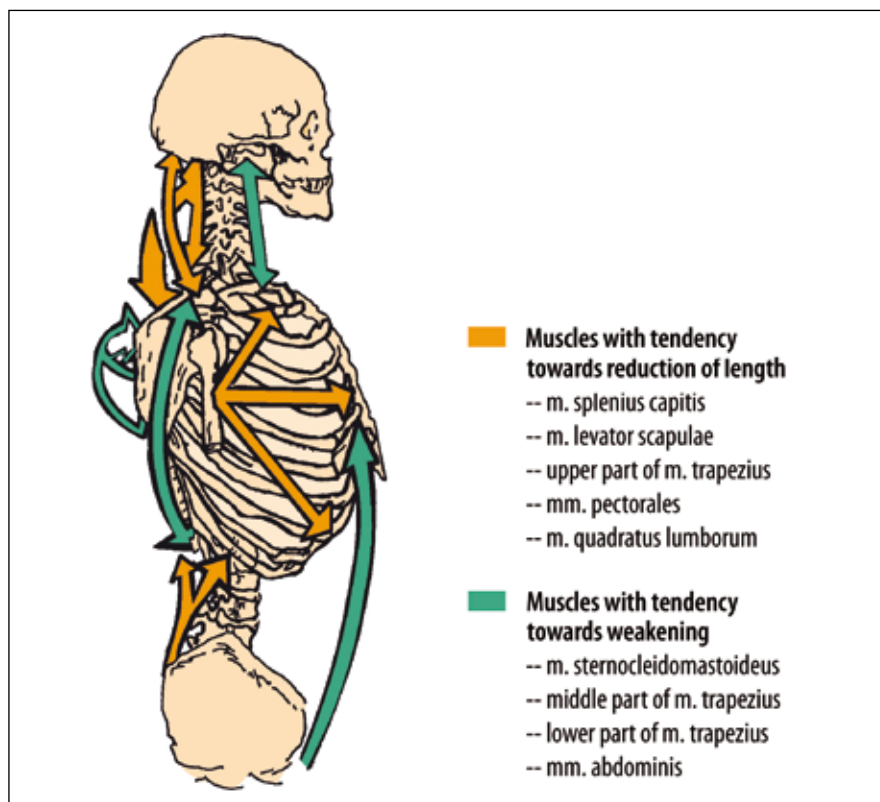


Fig. 1. Muscle groups of the neck and the trunk, subject to muscular dysbalance.

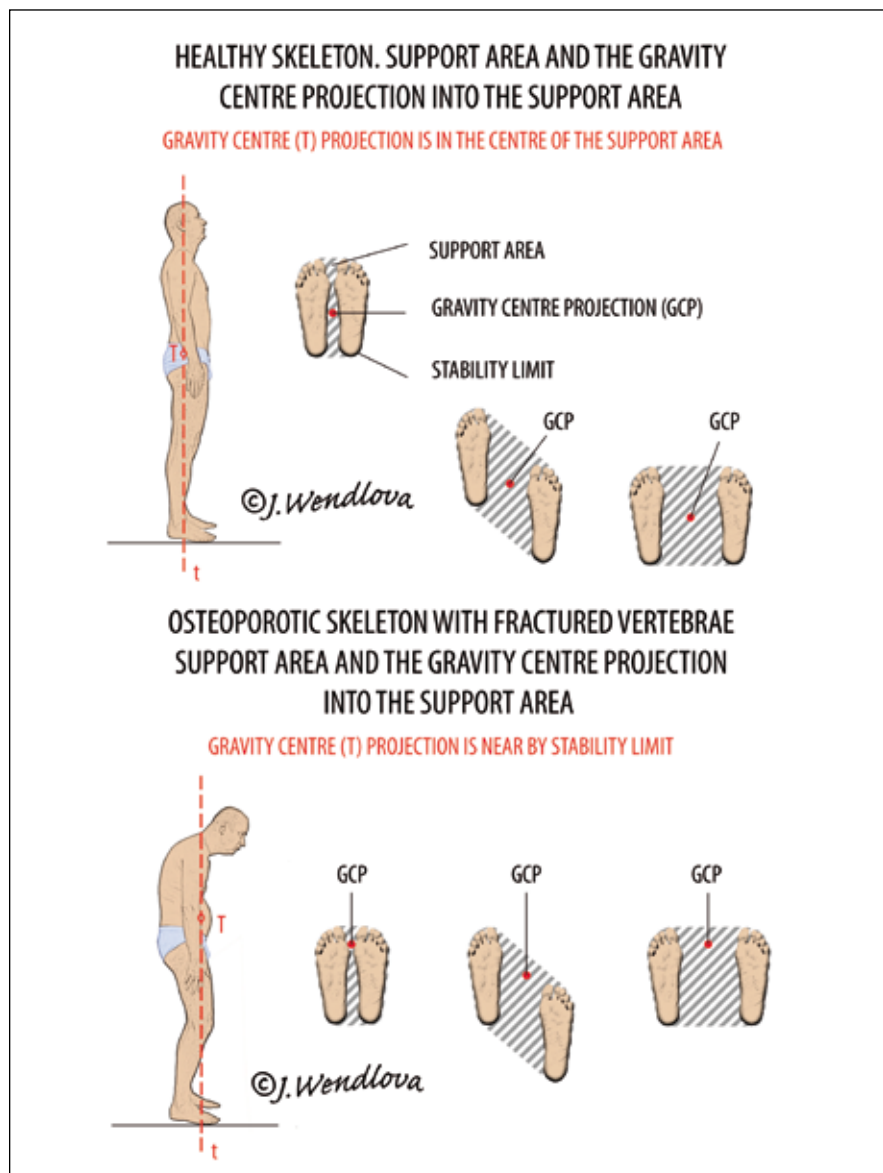


Fig. 2a.

forces acting upon the area of proximal femur [1–5], increasing the bone strength.

Carrying a backpack **on the back only**:

- for patients with osteoporotic vertebrae fractures [6].

Patients with osteoporotic vertebrae fractures

Osteoporotic vertebrae fractures represent the most frequent complication of osteoporosis and contribute to a partial or full invalidation of patients. Kyphosis, as a consequence of wedge-shaped deformation of fractured osteoporotic vertebrae in the

thoracic or lumbosacral area, conditions biomechanical changes in the organism with consequent grave clinical symptomatology:

- deviation of body's gravity centre from its normal position (fig. 2a),
- muscular dysbalance of trunk muscles,
- ileocostal friction syndrome (the rib arches rub on ala ossis ilii by walking and by motion) (fig. 3),
- pathological position of disci intervertebrales in the kyphosis and their non-physiological load (decrease of compressive forces upon ventral part and decrease of tension forces upon dorsal part of intervertebral discs),

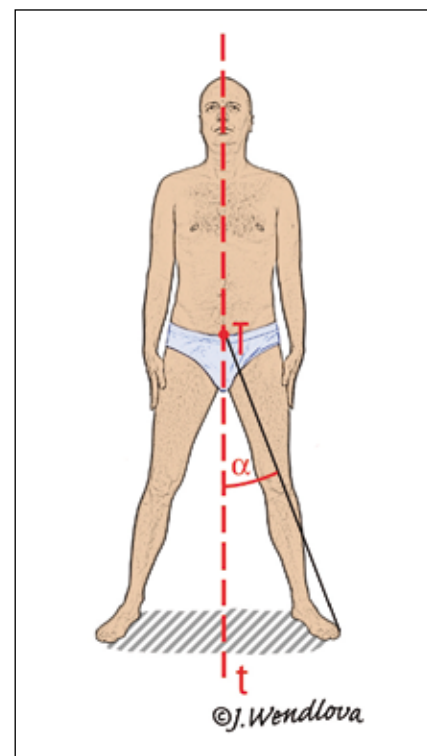


Fig. 2b. Stability angle.

- growth of compressive forces upon pulmonary parenchyma,
- development of cor pulmonale chronicum,
- ischemia or venostasis in intraabdominal organs, non-specific intermittent abdominal pain, chronic constipation,
- chronic backache [6].

It is recommended to carry a backpack on the back for patients with osteoporotic fractures. The following positive effects can be achieved:

- careful stretching of shortened pectoral muscles,
- strengthening the stretched and weakened dorsal muscles (balancing the muscular dysbalance),
- potentiating a moderate straightening of a spine and so mild the ileocostal friction syndrome and reducing tension forces acting upon dorsal muscles,
- reducing compressive forces acting upon organs of abdominal cavity,
- displacement of the deflected gravity centre closer to its physiological position – improving the patient's stability,

- reducing compressive forces acting upon ventral part and tension forces acting upon dorsal part of intervertebral discs in the site of pathological kyphosis,
- rise of the maximal breathing capacity,
- restriction of pain intensity in the back [6].

Impaired stability of body in osteoporotic patient with fractured vertebrae (explanation to fig. 2a and 2b)

Definitions

From the mechanical point of view the **balance constancy** in any posture of a man is determined by:

- the magnitude of the **support area**,
- the position of the body's **gravity centre** in relation to the support area,
- the distance of the body's median (the **gravity centre projection**) from the edge of the support area,
- the magnitude of the **stability angle**.

The **support area** of a man is represented by the area delimited by the outer limit of the body's contact area with the ground. The outer limit of this support area is called the **edge of the support area** or the **stability limit**. The **gravity centre** (T) of the body is represented by a mass point, concentrating the whole force of the body's gravity (the body mass). It is called also the mass centre. The body mass is equally distributed from this point to all sides. The **median** (t) is a vertical line passing through the gravity centre. The **gravity centre projection** (PT) is the point in the support area, crossed by the median.

The **stability angle** is the angle formed by the median and the line passing through the gravity centre and the edge of the body's support area.

The **stability of the skeleton** is increased by:

- the enlargement of the support area,
- the approximation of the gravity centre to the support area,

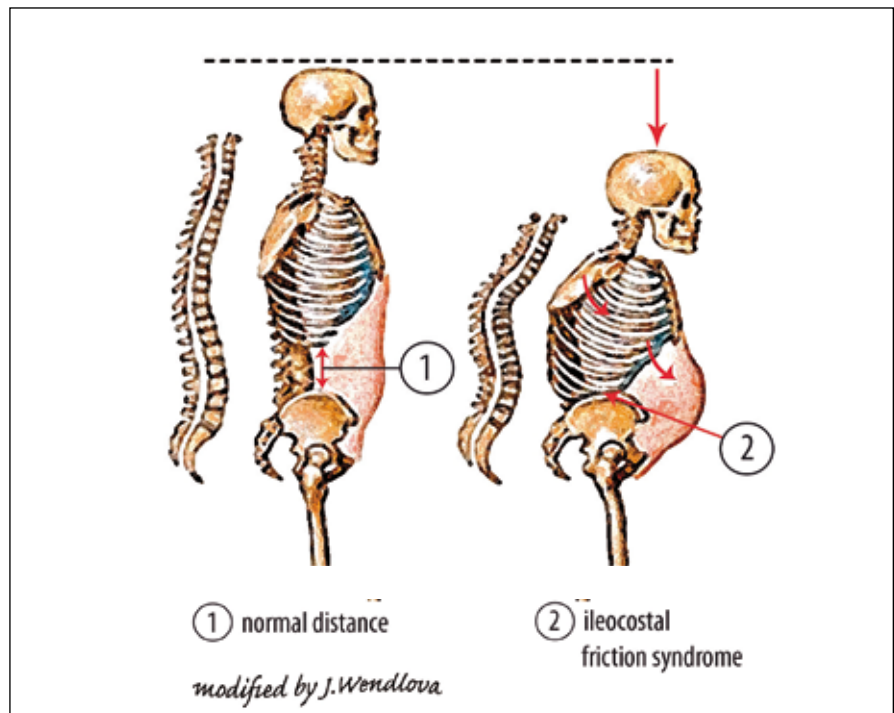


Fig. 3. Healthy and osteoporotic skeleton.

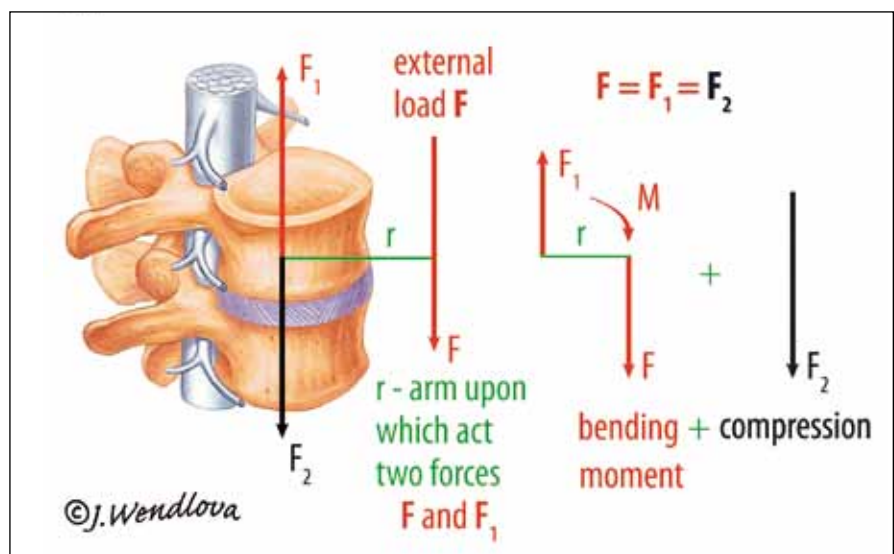


Fig. 4. Bending moment plus compressive force.

- the approximation of the median (gravity centre projection) to the centre of the support area,
- the enlargement of the stability angle.

When the gravity centre projection gets over the edge of the support area, i.e., beyond the stability limit, the man is in an unbalanced position and falls down to the ground. In patients with osteoporotic vertebral fractures the projection of the gravity centre into

the support area gets close to the stability limit of the support area in the upright position, and so these patients are prone to falls when bending forward or to sides [7].

Biomechanical analysis [7-9]

The importance of carrying a backpack can be explained by a simple biomechanical model, represented in fig. 4 and 5. The force F , situated in front of vertebrae, simulates the ex-

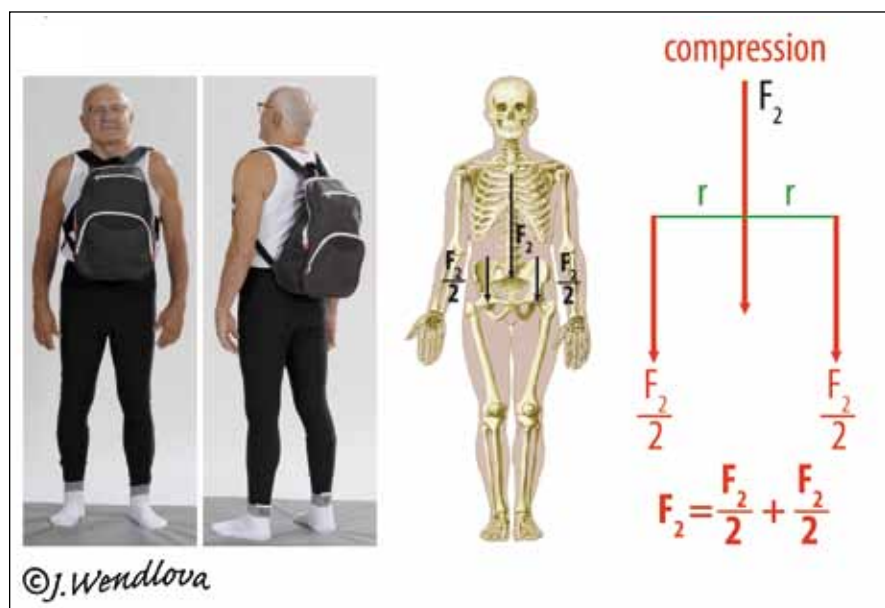


Fig. 5. Stressing the spine and the hip joints by the compressive force (F_2) and the distribution of the compressive force (F_2) from the spine into the hip joints while carrying a backpack.

ternal load (e.g., a backpack, worn in front). To determine the way, how the force F is transferred into the vertebrae, the model example is solved by situating a couple of forces in the axis of vertebrae. The couple of forces are two forces of the same magnitude, acting in the same ray and in the same point of application, however, they are of the opposite direction and sense, while it holds true that:

$$F = F_1 = F_2$$

The equilibrium status of forces does not change, as the effects of both added forces are mutually cancelled. This couple is also called the couple of zero forces.

Forces F_1 and F_2 produce a positive bending moment M on the arm r (acting clockwise) and the force F_2 is transferred as compressive force into lower situated vertebrae and through both hip joints into both lower limbs.

Solution result: External load by the force F is transferred to the vertebrae as a bending moment M and compressive force F_2 .

Carrying the backpack regularly (about an hour daily) and alternating its position in front and on the back balances the muscular dysbalance of the torso musculature. Simultaneously,

the compressive force in the vertebrae and in the proximal femur area is increased. The compressive force **stimulates osteoblasts to production of bone tissue (activation of osteoformation), increasing so the bone strength.**

Load magnitude

According to all, that we can not calculate the individual safe load for patient, we do not know the ultimate strength limit for osteoporotic and fractured vertebra in vivo, we can recommend only the very low load.

The patients with vertebrae fractures put a load of up to 1 kg into their backpacks [10], the patients without vertebrae fractures up to 2 kg.

Carrying a backpack in front

The backpack simulates the external load, stressing the spine to bend and press. The body defends itself against the bending moment of the backpack's gravity force (M), pulling the trunk to bend forward, by firstly isometric contraction of the abdominal and less dorsal muscles. These muscles are strengthened and the compressive force (F_2) is symmetrically (if the pelvis is in horizontal line) distributed from the spine through hip joints into

both lower limbs. Carrying a backpack in front makes, at the same time, the shortened pectoral muscles to stretch [6,11].

Carrying a backpack on the back

The body defends itself against the bending moment of the backpack's gravity force (M), pulling the trunk to bend backwards, by firstly isometric contraction of the dorsal muscles and less abdominal muscles, and in doing so, strengthens them. The backpack's gravity force also carefully stretches the shortened pectoral muscles and the compressive force (F_2) is also symmetrically distributed from the spine through the hip joints into both lower limbs [6,11].

In the Fig. 4 the force F (external load) will be situated in the back of the spine and the bending moment M will be negative (acting counter – clockwise).

Conclusion

Carrying a backpack regularly represents for the patient with uncomplicated osteoporosis as well as for the patient with osteoporotic vertebrae fractures a low-cost, easily accessible and effective daily rehabilitation, which is a part of a complex kinesi-therapy of the patient. It allows the patient to carry a backpack while making a small shopping, walking in a park or in easy terrain.

It is necessary to be aware that during the combination of carrying a backpack and Nordic walking certain magnitude of compressive forces is transferred from the patient into the poles and the rehabilitation effect of carrying a backpack is diminished [12].

Declaration – conflict of interests

The author declares, that she has no competing interests (financial or non financial).

Fig. 1 and 3 are modified by author from original anatomical pictures. Fig. 2a, 2b, 4, 5 are original – created by author.

Figurants: Ass. Prof. PhDr. Bohuš Hatiar, CSc. and Martin Petrik

References

1. Li J, Chen G, Zheng L et al. Osteoblast cytoskeletal modulation in response to compressive stress at physiological levels. *Mol Cell Biochem* 2007; 304: 45–52.
2. Basso N, Heersche JN. Characteristics of in vitro osteoblastic cell loading models. *Bone* 2002; 30: 347–351.
3. Steimetz T, Mandalunis PM, Ubios M. Effects of compressive forces on a bone modeling surface. *Acta Odont Latinoam* 1997; 10: 111–115.
4. Zhang S, Wu XY, Li YH. Bone adaptation and response to mechanical stress in bone. *Space Med Med Eng (Beijing)* 2001; 14: 368–372.
5. Scott A, Khan KM, Duronio V et al. Mechanotransduction in human bone: in vitro cellular physiology that underpins bone changes with exercise. *Sports Med* 2008; 38: 139–160.
6. Wendlová J. Osteoporosis – Kinesitherapy. Bratislava: Sanoma Magazines Slovakia 2008: 70–71.
7. Wendlová J. Osteoporosis – Kinesitherapy. Bratislava: Sanoma Magazines Slovakia 2008: 24–36.
8. Obetková V, Mamrilová A, Košinárová A. Theoretical mechanics. Bratislava: Publishing House of technical and economic literature ALFA 1990: 30–94.
9. Adamča LF, Marton P, Pavlík M et al. Theoretical mechanics. Bratislava: Publishing House of technical and economic literature ALFA 1992: 27–37.
10. Kaplan RS, Sinaki M, Hameister M. Effect of back supports on back strength in patients with osteoporosis: a pilot study. *Mayo Clin Proc* 1996; 71: 235–241.
11. Wendlová J, Wendl J. Didactics and method of therapeutic exercise in patients with osteoporosis. *Osteological bulletin* 1997; 2: 49–51.
12. Wendlová J. Nordic walking – is it suitable for patients with fractured vertebra? *Bratisl Lek Listy* 2008; 109: 171–176.

ass. Prof. Jaroslava Wendlová, MD, PhD.
www.nspr.sk/Nemocnica-Kramare
e-mail: jwendlova@mail.t-com.sk

Doručeno do redakce: 17. 5. 2010