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Impact of Bone Fracture on Muscle Strength and Physical Performance—Narrative Review

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Abstract

Purpose of Review Low muscle strength and poor physical performance are associated with high risk of fracture. Many studies assessed clinical and functional outcomes of fractures. Fewer studies analyzed the impact of fractures on muscle strength and physical performance.

Recent Findings Vertebral fractures (especially multiple and severe ones) are associated with back pain, back-related disability, lower grip strength, lower strength of lower limbs, lower gait speed, and poor balance. Patients with hip fracture have slower gait and lower quadriceps strength. Non-vertebral fractures were associated with lower strength of the muscles adjacent to the fracture site (e.g., grip strength in the case of distal radius fracture, knee extensors in the case of patellar fracture) and poor physical function dependent on the muscles adjacent to the fracture site (e.g., limited range of motion of the shoulder in the case of humerus fracture, gait disturbances in the case of the ankle fracture). Individuals with a fracture experience a substantial deterioration of muscle strength and physical performance which exceeds that related to aging and is focused on the period close to the fracture occurrence. After fracture, muscle strength increased and physical performance improved. The rate of normalization depended partly on the therapeutic approach and on the rehabilitation program. A subgroup of patients, mainly the elderly, never returns to the pre-fracture level of physical performance.

Summary The permanent decline of physical function after fracture may be related to the limitation of movements due to pain, low physical activity, poor health before the fracture, and reduced efficacy of retraining after immobilization.

Keywords Fracture · Muscle strength · Gait speed · Physical performance

Introduction

Interactions between bone and muscle are well known. Many studies concern shared precursors, genetic determinants, effect of bone cytokines on muscle metabolism and vice versa, *nutritional status, hormonal regulators or the impact of mechanical strain* [1–3]. Clinical studies show that higher muscle mass and strength are associated with higher bone mineral density (BMD), higher bone width, and better bone microarchitecture (mainly in the cortical segment) [4–9]. Low muscle strength and accelerated muscle decline are associated with more rapid bone loss and greater bone microarchitecture deterioration [10–12]. Prospective studies show that older individuals with poor muscle status (low muscle mass, size, strength, or density) have poor balance, gait disturbances, and higher risk of fall and fracture [6, 12–16]. Less attention is paid to the loss of muscle strength and deterioration of physical performance after fracture, although they result in substantial human and economic costs. The period of poor physical function is longer in older subjects and after major fractures (e.g., hip, pelvis). Many patients do not return to pre-fracture physical function. The long-term decline of physical function after fracture results in very high economic costs because these patients need more aid in daily life and more medical care (poor health, institutionalization). Human costs are also high and related to rapid decline of health and loss of independence. Physical incapacity and voluntary limitation of physical activity (e.g., due to the fear of falling) may result in the deterioration of the quality of life in terms of poor self-esteem and greater social isolation.

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Vertebral Fractures

The consequences of vertebral fractures include clinical manifestations such as back pain, loss of height, kyphosis, and reduced pulmonary function [17–26]. Many individuals self-report difficulties at the self-care, at the activities of daily life (e.g., bending, lifting, climbing stairs, reaching over the head, bathing, housework, gardening, rising from a lying into standing position), driving, caring for children, or practicing sport [20, 21, 27–30]. Vertebral fractures are also associated with poorer quality of life in terms of general health, physical activity, physical function, social function, and loss of quality-adjusted life years [17, 18, 22, 27, 31–33].

In a prospective follow-up of 7223 elderly women, an incident vertebral fracture was associated with higher risk of back pain, back-related disability, bed rest, and limited activity [34••]. In a 3-year prospective follow-up of 1058 older women, an incident vertebral fracture was associated with higher risk of back pain and greater deterioration of physical function and emotional status [22]. In a prospective 4.6-year follow-up of 4396 elderly men, an incident vertebral fracture resulted in higher risk of back pain, back-related disability, and of limitation of physical activity due to back pain [35].

The severity of clinical manifestations and deterioration of quality of life are greater in patients with lumbar fractures (vs. thoracic ones) and in those with recent vertebral fractures (vs. older ones) [17, 23, 25, 34••]. The severity of these disorders increased with the number and severity of vertebral fractures [17, 19, 22, 25, 26, 34••].

Muscle Strength and Physical Performance

Aside from the studies focused on the self-reported clinical symptoms, many studies assessed the association of vertebral fractures with muscle strength and physical performance assessed using standardized methods. After adjustment for confounders, patients with vertebral fractures had lower grip strength vs. controls in most [33, 36•, 37–40], but not all [26, 41•, 42], studies. They also had lower strength and power of the quadriceps and of the muscles of the arms in most [20, 33, 39], but not all [41•], studies. Individuals with vertebral fractures had poorer performance on the clinical test of strength of lower limbs (timed up-and-go test, chair stands, step test) in most [26, 31–33, 36•, 37, 38, 39, 43, 44], but not all [45], studies. The presence of vertebral fractures was associated with lower gait speed in most [20, 26, 39, 41•, 43], but not all [45], studies. Patients with vertebral fractures had impaired static and dynamic balance (functional reach, one leg standing, tandem walk, narrow walk) in most [20, 26, 36•, 37, 43], but not all [32, 41•], studies. Finally, patients with compression vertebral fractures had more often gait disturbances (e.g., greater step width, less stable body configuration in the anterior direction) and have higher risk of falling [36•, 46].

Deterioration of physical function increased with the number and severity of vertebral fractures [26, 37, 43, 44]. *The table presented in Fig. 1 shows that, in older men, prior vertebral fractures were associated with twofold higher odds of poor physical function defined on the basis of clinical tests* [36•]. *Multiple and severe vertebral fractures were associated with a proportionally higher risk of poor physical function after adjustment for relevant confounders.*

Similar patterns were found in men and in women. The results could vary according to the size of the cohort, control group (e.g., inclusion or exclusion of subjects who reported prior non-vertebral fracture), diagnostic criteria for vertebral fractures, clinical test, and confounders in the multivariable model.

Non-vertebral Fractures

Studies on consequences of non-vertebral fractures are concerned mainly on major fragility fractures (hip, distal radius, proximal humerus). Fewer studies concerned other non-vertebral fractures.

Hip fracture is associated with high mortality, temporary or permanent institutionalization, functional decline, loss of quality-adjusted life years, anxiety/depression, and loss of the ability to perform self-care and activities of daily life [29, 47–50]. Patients with hip fracture experience numerous lower body limitations and impaired walking ability and often need walking aid or wheelchair [29, 48, 49]. Their reduced mobility is partly related to severe pain and fear of falling [51]. Other proximal non-vertebral fractures (pelvis, femur, clavicle, rib, humerus) are associated with higher mortality, high risk of adverse effect during hospitalization, substantial loss of autonomy, and higher risk of nursing home admission after hospitalization [29, 47].

Prior Fracture, Muscle Strength, and Physical Performance

Hip Fracture

In elderly individuals who sustained a hip fracture, the quadriceps strength of the fractured limb was significantly lower compared with the non-fractured limb [52] and compared with the non-fractured age-matched controls [53]. Patients who had hip fracture and hip hemiarthroplasty also had significantly lower hip abductor strength on the fractured side vs. the healthy side [54]. Lower muscle strength on the fractured side was correlated with measures of physical function (e.g., walking speed, stair climbing speed) and with poor performance on the timed up-and-go test [52, 54]. Patients with hip fracture had lower gait speed and poor performance on the chair stand test [53, 55, 56]. They also had high risk of recurrent and

Variable	N	OR (95%CI)—without adjustment for lower limb RASM	OR (95%CI)—with adjustment for lower limb RASM
Vertebral fracture—yes vs. no		2.45 (1.34 – 4.48)^{b}	2.59 (1.41 – 4.76)^{c}
Vertebral fracture severity—none	798	1.00$^{\#}$	1.00$^{\#}$
Grade 1	17	1.98 (0.47 – 8.35)	2.17 (0.49 – 9.58)
Grade 2	56	2.12 (1.01 – 4.44)^{a}	2.28 (1.08 – 4.82)^{a}
Grade 3	19	4.24 (1.38 – 13.0)^{c}	4.04 (1.31 – 12.5)^{b}
Non-vertebral fractures—yes vs no		2.36 (1.27 – 4.38)^{b}	2.28 (1.22 – 4.25)^{b}
Non-vertebral fractures—0	790	1.00$^{\#}$	1.00$^{\#}$
1	84	1.81 (0.90 – 3.63)	1.76 (0.87 – 3.54)
>1	16	7.56 (2.13 – 26.9)^{b}	7.05 (1.96 – 25.3)^{a}
All fractures—yes vs. no		2.56 (1.55 – 4.24)^{d}	2.57 (1.55 – 4.27)^{d}
Number of all fractures—none	723	1.00§	1.00§
1	106	1.91 (1.03 – 3.54)^{b}	1.92 (1.03 – 3.58)^{a}
>1	61	3.99 (1.97 – 8.09)^{c}	3.96 (1.95 – 8.05)^{c}

Both models are adjusted for age, current smoking, alcohol drinking, leisure and occupational physical activity, diabetes mellitus, prior stroke, apparent free testosterone concentration, 25-hydroxycholecalciferol, C-reactive protein, and abdominal aortic calcification.
$^{a}p < 0.05$; $^{b}p < 0.01$; $^{c}p < 0.005$; $^{d}p < 0.001$; *p* for trend; $^{\#}p < 0.005$ $^{\S}p < 0.001$.

Fig. 1 Association of prior fractures with poor physical function assessed using multivariable models. The score of poor physical function was assessed on the basis of clinical tests (chair stands, static balance, tandem walk forward and backward). RASM, relative appendicular skeletal muscle mass; OR, odds ratio. (*Reproduced from Szulc* et al *[Ref.* 36] *with permission from John Wiley and Sons*)

injurious falls [57]. In this group, low grip strength, low strength of the muscles of the lower limbs, and high level of disability at the activities of daily life were associated with higher risk of injurious fall.

The strength of the muscles of the injured limb increased and the physical function improved with time but returned to the pre-fracture level only in a half of patients [49] (Fig. 2). Of note, rapidity of recovery in physical function (e.g., muscle strength, gait speed, balance, timed up-and-go test) partly depended on surgical technique and rehabilitation approach [58–62].

A fracture is associated with loss of strength of the muscles having insertions on this anatomical site. Hip abductors have their insertions on the greater trochanter. Patients with a greater trochanter fracture had lower abduction strength on the injured side compared with the healthy side [63]. Hip flexors have insertions on the lesser trochanter. Patients with the lesser trochanter fracture had lower strength during the flexion of the affected hip compared with patients who had pertrochanteric fracture but without damage of the lesser trochanter [64].

Distal Forearm Fracture

During the first weeks after the distal radius fracture, grip strength of the fractured limb was lower compared with the unfractured limb [65–69]. Distal radius fracture was also associated with markedly decreased pronation and supination strength [65, 67]. At the injured wrist, the range of motion and rotation in all axes was reduced and local disability was more severe compared with the uninjured wrist [66–68•]. Lower grip strength and poor grip mobility were associated with greater wrist disability (e.g., inability to turn cards or to move small objects) [70].

Grip strength, pronation and supination strength, and the range of motion and rotation in all the axes increases progressively [65, 67–69, 71] (Fig. 3). After 2 years, they approached the values of the contralateral uninjured wrist except pronation and supination strength [72].

The degree and the rapidity of the recovery in the strength and physical function varied between the studies. The recovery rate partly depended on the therapeutic approach (nonoperative vs. operative, type of surgical technique), anatomic realignment, presence of malunion, and on the early mobilization/rehabilitation [68•, 73–77].

Proximal Humerus Fracture

Studies concerning proximal humerus *fracture focused* on functional range of motion and data on muscle strength are limited. Most of the studies jointly assessed patients with fractures of different degree of severity, patients treated nonoperatively or operatively, and those without or with prostheses. Not all studies accounted for accompanying conditions such as brachial plexus injuries or fatty atrophy of the muscles [78, 79]. The time elapse from fracture and/or surgery varied between the studies. *Some articles are descriptive without statistical analysis of the loss of function or muscle strength vs. the non-fractured arm or control group* [80–82]. *Some studies focused on the comparisons according to the type of fracture or according to the method of treatment, but not on the relative loss of strength or function* [83–86].

During the first years after fracture, patients had decreased abduction strength of the fractured arm compared with the contralateral arm [87]. The studies performed several years after fracture and/or surgery show the remote sequelae. Even more than 3 years after the fracture, the muscle strength of the fractured limb was slightly lower for some (isokinetic flexion,

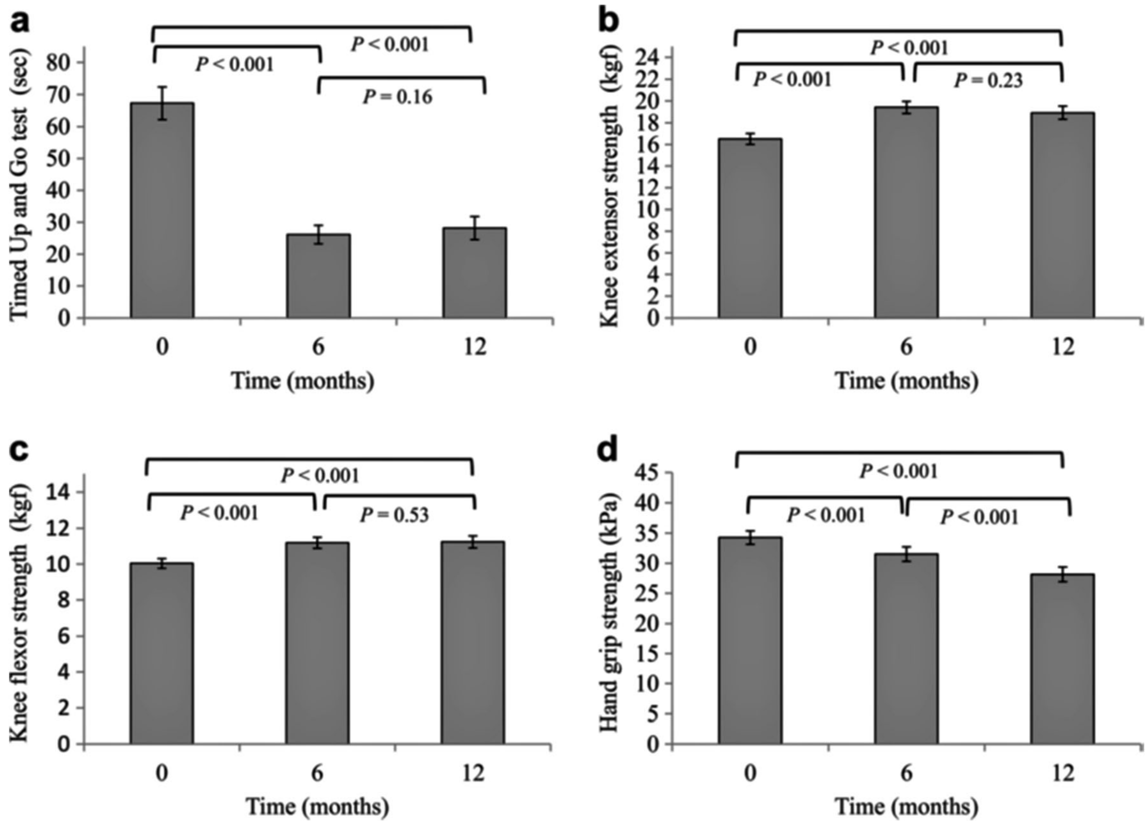


Fig. 2 Temporal profiles of performance in the (a) timed up-and-go test, (b) knee extensor strength (kg), (c) knee flexor strength (kg), and (d) hand grip strength, in older adults ≥ 65 years after hip fracture ($n = 173$). Values are adjusted mean values (LSM ± SE) from multivariable linear mixed models adjusted for the treatment group of the trial and an interaction treatment × time, as well as for age, gender, and bodymass index (kg/m^2), Charlson comorbidity index, living situation (at home vs. assisted living/nursing home), total score of the mini-mental state examination, and baseline 25-hydroxyvitamin D. Baseline measurements (month 0) were performed on days 1–12 after hip fracture surgery. LSM, least square mean (an adjusted mean value of an outcome variable; i.e., the originally observed mean value of an outcome variable was adjusted for the influence of possible confounders stated in the description of the model adjustments above); SE, standard error. (*Reproduced from Fisher* et al. *[Ref.* 59] *with permission from Springer*)

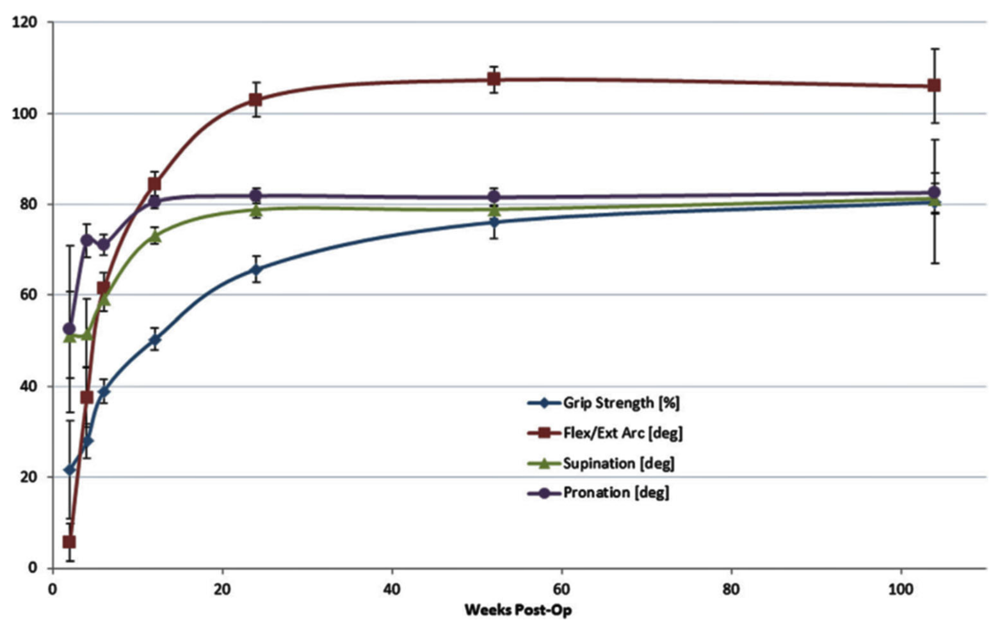
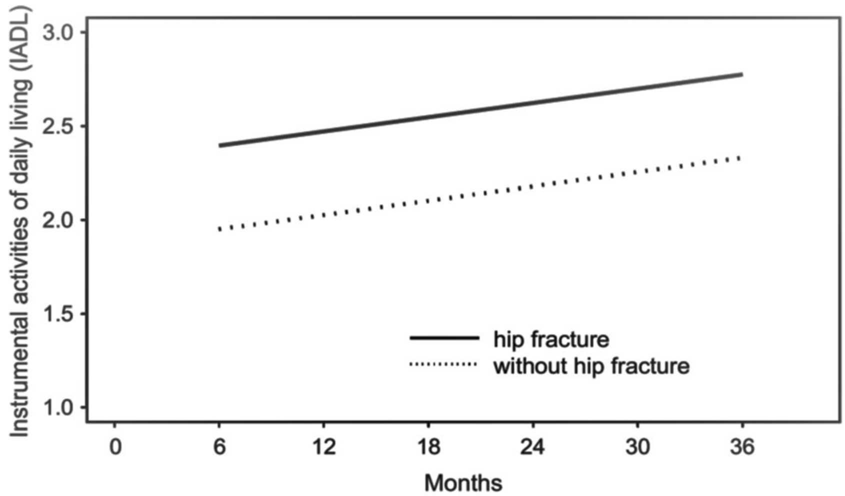


Fig. 3 Recovery of outcome measures: grip strength (percentage of the contralateral side), range of motion (degrees)—flexion-extension (Flex/Ext Arc), supination, and pronation. Measures are presented as a function of postoperative time (weeks). Error bars represent 95% confidence intervals. (*Reproduced from Swart* et al. [*Ref.* 67] *with permission from ELSEVIER*)



Additional impairments/ month	Between group differences
0.013 (*P*=.001)	0.45 (*P*=.01)

Fig. 4 Difficulty in performing instrumental activities of daily life (IADL) over time between hip fracture and non-hip fracture subjects. On average, patients after hip fracture had difficulty in a higher number of IADLs (difference between the means—0.45, $p = 0.01$). The average number of new impairments was 0.013 per month ($p < 0.001$) and was similar in both groups. (*Reproduced from Young* et al. [*Ref.* 53] *with permission from ELSEVIER*)

adduction), but not all, motions compared with the healthy side [86, 88, 89]. Lower shoulder strength was associated with greater disability of the shoulder assessed by clinical scores [88]. Proximal humerus fracture was associated with limited range of motion of the shoulder (mainly abduction or anteversion) and reduced ability to perform everyday activities of personal care [83, 86, 87, 89, 90]. During the period after fracture, pain decreased, the range of motion of the shoulder increased progressively, and the capacity for personal care improved [87, 90, 91].

The impact of the treatment on muscle strength, range of motion, and disability varied between the studies according to the comparison, e.g., operative vs. nonoperative treatment, different surgical techniques, different types of prostheses, etc. [83–87, 92]. Fatty infiltration of the muscles of the shoulder was associated with slightly lower strength but no change in the range of motion [78].

Other Non-vertebral Fractures

Pelvic fracture may be associated with substantial gait abnormalities (slower gait speed due to lower cadence and lower step length) and with lower strength of hip muscles [93]. The fracture followed by immobilization results in a loss of muscle strength which concerns mainly, but not only, the affected side and is greater at the level of the muscles which have insertions close to the fracture site [91]. These abnormalities are most severe in the first weeks after the fracture and partly normalize afterwards [93, 94].

In subjects who had patellar fracture, isometric strength, dynamic power, and endurance were lower on the injured vs. the uninjured side [95]. The deficit was greater for the extension (50–60%) than for the flexion movement (30%). Patients experienced a significant atrophy of thigh muscles and impaired motor control and coordination of the injured limb [95]. Physical function improved over time but 1 year after the fracture, physical function of the injured limb was poorer vs. the uninjured limb [95]. The patients experienced a deficit in knee extension strength and knee pain in the injured leg as well as limitation of the everyday activities even 8 years after the patellar fracture [96].

Ankle fractures may be associated with poor outcomes in terms of gait recovery [97]. Patients after ankle fracture had lower gait speed due to lower step length and lower cadence [98, 99]. Gait disturbances were associated with lower anteroposterior and vertical acceleration of the trunk, shorter single limb support, and reduced range of motion of the fractured talocrural joint, especially in the sagittal plane (flexion/extension) [98–101]. The deficit in the strength of the leg muscles, poor static balance (single-leg stance), and limitation of the joint movements persisted for more than 1 year after fracture [100–103].

Few studies assessed various fractures jointly. One study assessed three groups: subjects with fracture (vertebral, non-vertebral) and moderate or severe pain in the month prior to the study, subjects with fracture but without pain, and controls [104]. Those with fracture and pain had the lowest grip strength and used a walking aid most often. They had lower gait speed and poorer performance on the timed up-and-go test vs. the two other groups. In a cohort of older men, history of non-vertebral fracture was associated with slightly lower grip strength, poor physical performance, and slightly higher risk of multiple falls [36•].

Incident Fracture, Muscle Strength, and Physical Performance

Prior non-vertebral fractures were associated with lower muscle strength and poorer physical function. The deficit concerned mainly the muscles close to the fracture site. The significant difference in muscle strength between the fractured and the non-fractured limb indicates that the local loss of muscle strength is due to the fracture itself. It also shows that this deficit is not a mere consequence of bed rest and does not reflect the pre-fracture low muscle strength which contributed to the fracture occurrence. However, this difference may overestimate the loss of strength due to the fracture because the patient could overload the non-fractured limb during the consolidation phase and strengthen its muscles. After the initial drop, physical function and muscle strength increased over several months. However, many patients experienced some permanent deficit of physical function vs. the pre-fracture status, which may be partly due to the fracture and partly due to aging itself. In addition, they could have more rapid deterioration of physical performance after the recovery from fracture. However, few prospective studies followed up in parallel individuals with fracture and non-fractured controls.

The elderly who sustained a hip fracture experienced greater increase in difficulty in activities of daily life, in the upper body limitations (e.g., reaching up over the head) and in the lower body limitations (e.g., walking, kneeling) compared with controls without hip fracture [105•]. In the prospective analysis (SOF study), women who had an incident distal forearm fracture had greater functional decline (e.g., meal preparation, housekeeping) vs. the controls who did not have fracture [106]. In a cohort of elderly individuals, an incident fragility fracture was followed by a significantly greater loss of grip strength and significantly greater deterioration of physical performance compared with the participants who did not have fracture [107••].

By contrast, the loss of quadriceps muscle strength after an incident clinical fracture was similar to the pre-fracture rate of loss in elderly men and women [108]. Elderly women who recovered from hip fracture had poorer physical function compared with the non-fractured controls [53]. However, further loss of muscle strength, physical performance, and ability to perform activities of daily life assessed prospectively after the recovery was similar in both groups (Fig. 4).

Thus, the prospective studies show that subjects who sustain a fracture experience a substantial deterioration of muscle strength and physical performance which exceeds that related to aging itself and is concentrated on the period close to the fracture occurrence.

Permanent Physical Decline After Fracture—Risk Factors

Mechanisms underlying the permanent decline in physical performance are poorly understood. The possible determinants may be divided into two groups: local and general.

Local factors are related to the anatomical site of fracture. Multiple or severe vertebral fractures are often associated with back pain, deformation of thorax, and abnormal vertical body axis [109, 110]. They may result in voluntary or involuntary limitation of movements of the upper half of the body (e.g., spine extension-related activity) and of walking-related activity [111]. The limited activity may be temporary or permanent. Risk factors of poor recovery are higher age, severe back pain, low physical activity, and crush fractures (vs. wedge or biconcave ones) [25, 43, 111]. A patient may limit movements of the fractured limb (voluntarily or involuntarily) in case of chronic pain due to, e.g., surgical technique, consolidation problems, or suboptimal recovery of the long axis of bone [48, 112, 113]. Importantly, in the elderly, voluntary limitation of activity may contribute to the development of real incapacity.

The general determinants may be divided into lifestyle-related factors, health status, and aging-related decline of the muscle status. Patients after major fragility fracture, surgical treatment, and immobilization often have low physical activity [114, 115]. The memory of the fall-trauma-pain-fracture-immobilization may result in the fear of another fall-fracture sequence and further voluntary limitation of physical activity [116, 117]. In the elderly, reduced physical activity may trigger a vicious circle leading to a severe decrease in muscle strength, physical performance, and independence [118, 119].

The importance of the general health status is most evident in the case of hip fracture. Pre-fracture co-morbidities (e.g., cardiovascular, renal, respiratory, or liver diseases; diabetes; dementia) are associated with higher mortality, higher-risk surgical and medical complications, and general functional decline [120–124]. *The risk of these diseases increases with age and their prevalence is high among hip fracture patients who are mainly the frail elderly.* However, the emergency surgery for hip fracture is associated with markedly higher risk of postoperative mortality and complications compared with patients matched for age and preoperative health status but receiving elective total hip replacement for hip osteoarthritis [125]. Thus, the poorer the pre-fracture status, the higher is the risk that the patient will not fully recover and not return to the pre-fracture physical performance.

After a fracture, immobilization and disuse are followed by a rapid loss of muscle mass and strength [126]. Immobilization and disuse induce a similar decrease in muscle mass, volume, strength, power, specific force, and capacity in younger and older individuals [127–130]. Then, retraining counteracted the decline in muscle strength and fully restored the pre-disuse values of the muscle characteristics in young individuals. By contrast, in older subjects, retraining after disuse did not fully restore the pre-disuse volume, strength, power, and capacity of the muscles. Reduced efficacy of retraining after bed rest may resemble the immobilization after a fracture of the hip, pelvis, or femur [127]. Localized reduced recovery in muscle strength and capacity after local limb cast immobilization may resemble localized impairment of muscle function after a fracture of the ankle or distal forearm [128–130]. This attenuated recovery in muscle strength and capacity after immobilization or disuse may result in permanent decline of physical function after fracture in older individuals.

Limitations

As mentioned above, lower muscle strength and poor physical performance are risk factors for fracture. Thus, if a subject is examined only after fracture, it is not possible to apportion the post-fracture physical decline from the poor pre-fracture status. For instance, 6 months after distal radius fracture, postmenopausal women had lower grip strength of the non-fracture side, lower leg muscle strength, lower muscle density (forearm, calf), and poorer performance on the timed up-and-go test and on the chair stand test [131, 132]. Distal radius fracture is not supposed to influence the dynamic balance or to decrease the strength of the contralateral hand (it would rather increase because the patient used mainly this arm). Thus, these differences may rather reflect poor muscle strength and physical performance before the fracture which contributed to the fall and fracture.

In elderly patients 1 month after hip fracture surgery, pre-fracture osteoporosis was associated with lower gait speed after fracture after adjustment for age and sex [133]. However, the design of the study did not permit to account for the pre-fracture gait speed. Poor pre-fracture health could increase the risk of osteoporosis before the fracture and the risk of poor physical function after the fracture in parallel but independently of each other.

In a cohort of elderly men, the presence of vertebral fracture was associated with poor performance on the chair stand test [41•]. In this cohort, the poor performance on this test (mainly inability to perform it) was also associated with higher risk of incident fracture. Again, it is not possible to determine whether the poor performance in men with prevalent vertebral fracture was its consequence or its risk factor in the past prior to the recruitment.

It is also important to check how age and other confounders are handled in statistical models. In cross-sectional studies, individuals with fragility fractures are usually older and have poorer health status compared with those without fracture. These two factors may contribute in parallel to high risk of fracture and to poor physical function. In prospective studies, individuals who had a fracture also got older during the follow-up and the post-fracture changes in their physical function could partly depend on the aging itself [53]. The rate of aging-related deterioration of physical function increases with age. Thus, prospective observational studies limited to patients with fractures do not permit to apportion the physical decline due to the fracture from that related to aging and deterioration of health status themselves.

There are also additional limitations, e.g., over-mortality and higher dropout among the oldest and the sickest patients with fracture. Similarly, the individuals who experience the greatest loss of muscle strength and physical performance do not volunteer for clinical studies. These phenomena introduce a bias and an underestimation of the fracture-related physical decline. Various studies assessed different clinical tests and scores, and the time elapse since the fracture varied between the studies. In the case of vertebral fractures, this time elapse could not even be defined. As the deterioration of the physical function is the most severe in the first months after the fracture, this difference in time elapse could contribute to the discordant results. Patients with vertebral fractures differed in terms of number and severity of fractures and of diagnostic criteria used in various studies.

Fracture, Muscle, Physical Function—Societal Perspective

The consequences of fractures as concerns their impact on muscle strength and physical function are multiple. They are associated with major human costs in terms of pain, poor mobility, loss of independence, loss of working days and professional activity, and deterioration of quality of life (poor physical function, limited social interactions) [29, 48, 105•, 134]. Post-fracture deficit in physical function (low muscle strength, poor balance, inability to perform the activities of daily life) may significantly increase the risk of falling [36•, 135, 136].

Musculoskeletal disorders (including osteoporosis) and falls belong to the five most expensive diseases in the USA jointly with low back and neck pain, diabetes mellitus and ischemic heart disease [137]. *Between 1996 and 2016, the costs of musculoskeletal disorders and falls increased by 3–5% annually* [137]. *Between 2000 and 2011, osteoporotic fractures resulted in greater number of hospitalizations (4.86 million) than stroke (2.97 million) or myocardial infarction (2.89 million)* [138]. *Osteoporotic fractures occurring mainly in the frail elderly are expensive on the per event basis, e.g., an emergency hip arthroplasty for hip fracture is twice as expensive as an elective hip arthroplasty for osteoarthritis* [139].

In older adults, falls and fall-related injuries (mainly fractures and wounds) result in many hospitalizations and emergency department (ED) visits (e.g., 56,363 and 138,581, respectively, in 2014 in Florida) [140]. *In the elderly, falls are* *responsible for 50% of deaths and 60% of ED visits related to unintentional injuries* [141]. *Fall-related hospitalizations and ED visits induce major healthcare spending which increases every year* [142]. *In 2015 in the USA, medical costs attributable to fatal and nonfatal falls were $49.5 billion, including $754 million for fatal falls* [143]. *Overall, fractures, falls, and related injuries constitute a huge economic burden related to hospitalization and ED visits.*

In addition, the deterioration of physical function after fracture has substantial economic costs related to rehabilitation, institutionalization, home aid services, or durable home equipment [144, 145]. Therefore, programs of extended or accelerated rehabilitation after fracture were developed. Patients receiving more intense physical therapy had improved trunk strength, higher gait speed, better physical performance, less disability, and less psychological symptoms compared with the controls receiving usual rehabilitation [61, 146–148]. Cost-effectiveness analyses show that such programs permit to accelerate rehabilitation after fragility fractures and to improve functional outcomes without additional cost [61, 148–150]. They may reduce clinical and economic impacts of the fractures, especially in the professionally active young adults and in the elderly having sustained fragility fractures. However, further studies are needed to better define the deficit in physical performance and rehabilitation needs according to the type of fracture, complications (e.g., nerve damage), and the applied method of treatment (operative vs. nonoperative, type of prosthesis, etc.). In particular, we need more programs of early and accelerated rehabilitation permitting to reduce the post-fracture functional decline in the elderly.

Compliance with Ethical Standards

Conflict of Interest Nothing to declare.

Human and Animal Rights and Informed Consent Not applicable.

Consent to Participate Not applicable.

Consent for Publication Not applicable.

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• Of importance
•• Of major importance

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